EUROPEAN HYDRO-ELECTRIC POWER DEVELOPMENT

BEING A SHORT DESCRIPTION OF INSTALLATIONS IN FRANCE, ITALY AND SWITZERLAND

BY

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INDEX.

INTRODUCTORY.

In that branch of engineering science devoted to the development of hydraulic works and equipment for the generation of power, European engineers undoubtedly lead. Especially in Central Europe, in the vicinity of the Alps, was this subject reduced to a science long before an equal progress was made in America. This was due to the necessities of those countries, poor in coal or other fuel and rich in water powers of either low or high heads.

In the practice of to-day, in design and construction of European installations, their engineers have displayed a boldness of conception and a wealth of ingenuity, especially in those civil, hydraulic and mechanical divisions, which go to make up the diversified engineering necessary in this class of work. In such manner the design and the excellence of the equipment manufactured in European shops has reached a quality and a degree of efficiency to which American builders have not yet attained, or, if so, have accomplished the result only by employing European designs, designers or workmen.

On the electrical side the positions are reversed, and it seems to be generally admitted that American design and construction take precedence. There are, however, many points in the European systems with which engineers on the American side of the water might do well to familiarize themselves. Among these might be noted the wide power distribution features, the very general use of small motors in what might be termed household industries, and the popular education which has been directed by the Governments and power companies, looking to more universal use of electric power.

The following articles are the result of personal visits and studies of many notable plants in France, Italy, and Switzerland made by the writer in 1906. They were written primarily for the columns of "The Canadian Engineer," published during the same year. The articles do not aim at detailed description, but the purpose has been rather to describe in a brief manner those general and special features which may prove interesting, and possibly instructive, reading for the members of the profession, particularly in Canada.

January, 1907.

I.

FRENCH PLANTS IN THE VICINITY OF LYONS.

Lyons Installation on the River Rhone.

The city of Lyons with its population of half a million, is second in size, but first in industrial importance, among the provincial cities of France. This distinction is largely due to its geographic situation, since it is practically in the centre of the country, and is located at the confluence of two navigable rivers, the Rhone and the Soane; hence, secures for it a large provincial trade, and makes it an ideal distributing centre. The surrounding cities and towns contribute their share toward this activity; notably St. Etienne, with its steel works—the largest in France.

Lyons, as a user of power for manufacturing purposes, offered an attractive field for enterprise. It is not surprising, therefore, that in this city one of the earliest European hydro-electric plants of large dimensions was installed. The diverse character and limited extent of its respective manufactures calls for relatively small quantities of power, requiring a varied distribution and numerous units. The main demands for mixed power come from its silk, fancy goods, leather, wine, brewing and light metal establishments. The total value of manufactures in Lyons amounts to about $100,000,000 annually, mainly silk, of which, over one-half the world's supply is said to pass through the warehouses of Lyons.

The Société des Forces Motrices du Rhone first undertook in 1894 the construction of a hydro-electric plant for the purpose of transmitting power to Lyons, a few miles distant, and thus became one of the pioneer European hydro-electric power producers. The site chosen for development was on the Rhone, a few miles above Lyons, and was such that high tension transmission was unnecessary. The result now is, that as in similar instances in America, a large industrial suburb, Ville-urbanne has sprung up near the generating station, notable for its lack of chimneys and its uniformly neat appearance.

For a distance of about ten miles above the generating station, the Rhone flows through a very irregular bed, consisting of a network of rapids and small swift streams, among gravel islands, in a broad valley, having a total fall of about 35 feet. The main channel is canalized by the Government for shallow draft. The general scheme of the power development comprises a head canal from the Rhone above the rapids to a power house site, thence a tail race canal to an outlet in the Rhone below the rapids, a total distance of about 11 miles, the whole known locally as the "Ca-

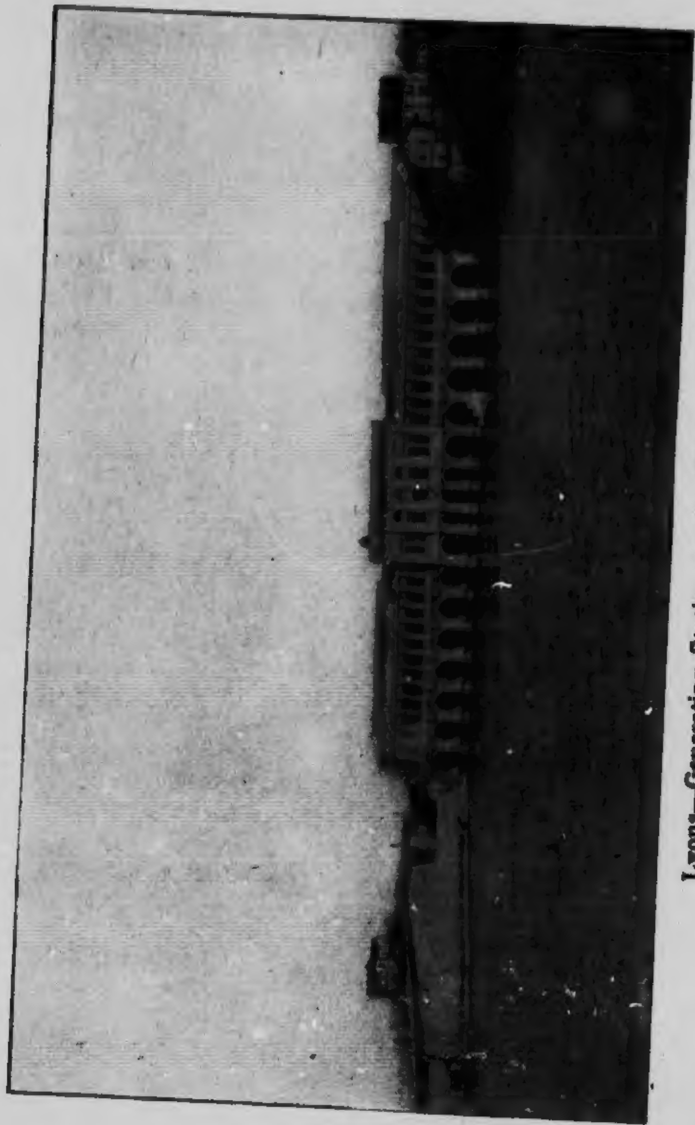
nal de Jonage." This arrangement affords a working hydraulic head of about 38 feet. The amount of water available is limited by the natural conditions and the requirements of the Government to from 3,000 cubic ft. per second at low water, to 4,800 at high water. The diversion of this water from the river, made necessary the construction of a canal of a minimum depth of 8 feet, with locks for the passage of light draft vessels, so that in case of need the Government could use it in conjunction with the main channel.

The upper portion of the canal follows an old river channel, while the main portion, cut through gravel, is heavy excavation to a wet section of about 200 ft. width. The canal is spanned by nine very substantial bridges. The generating station of itself forms the dam across the canal necessary to secure the head of water and at one end a lock for passing vessels is inserted.

The generating station has frequently been noticed in the technical journals during the past few years, it is not the intention in this article, therefore, to enter into elaborate details, but simply to set forth the engineering features of this notable installation. The building itself is about 475 feet long, and is built largely of concrete, trimmed with stone and tiles. The units are directly connected; of the vertical shaft type, 16 in number, each of about 1,250 net H.P., under normal conditions of the river; there are also 3 exciter units. Water is led to the turbines from separate bays on the upstream side of the station, each having its own screens and sluice gate. The latter is unique, as being in the nature of a cylindrical drum, 10 ft. in diameter, closing the top of a vertical inlet pipe. It is raised and lowered by a chain hoist worked from within the station shown on the right hand side of the interior view of same.

The units are arranged in line at about 27 ft. centres. The right central units, four on each side of the central bay—which contains the exciter units and switchboards—are operated by Jonval turbines made by Escher Wyss & Company, of Zurich, the installation of which was completed about 1897. These are of a special type, having a three stage runner with downward discharge into a draft tube, and water fed to it through three separate and parallel distributors or guides at about 45 degrees; all fitted with cylinder gates. The thrust is provided for by a large disc or piston about 6 ft. diameter, attached to the shaft within, and at the top of the case. The closed chamber on the upper side of the piston is connected to the tail race. Regulation is secured by a special governor, consisting of a rotating disc and servo-motor actuating valves in conjunction with a high pressure oil pump, by which the gates of the turbine are operated. This turbine gives an

efficiency of about 76 per cent. at full load, and the governor is said to regulate within a speed variation of 4 per cent. on a change of half load. The other eight main units, four at each end, were installed in 1902, also by Escher

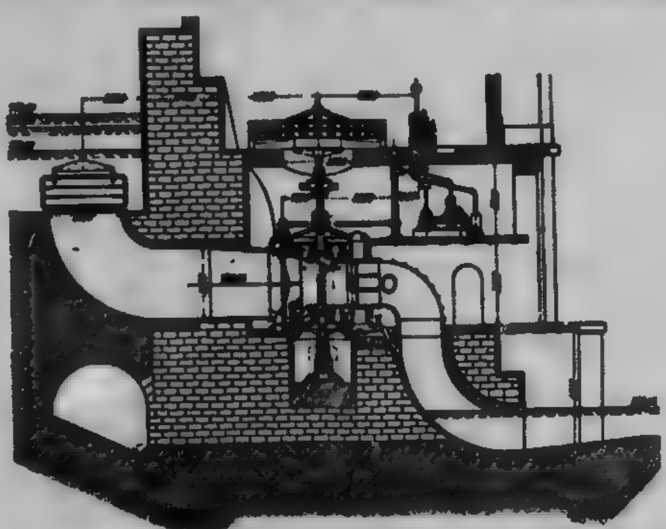


Lyons—Generating Station on the Rhone.

Wyss & Co., and are of the Francis type, having a double runner with central outward discharge, and are said to give an efficiency of about 83 per cent. It is to be noted that the latter type discharges water in the tail race with less air and commotion than does the Jonval.

The electrical apparatus is very simple for a station of such magnitude. The generators are wound for three phase, 50 cycles, and 3,500 volts, and revolve at 120 R.P.M. The exciters (3 separate turbine units) provide 170 K. W. each, and revolve at 250 R.P.M. All generators are run in parallel through a simple switchboard directly to the transmission and distribution lines without transformers. The electrical apparatus was built and installed by Brown Boveri & Company, of Baden, Switzerland.

The operation of t. e station requires comparatively few attendants, being distributed as follows: Eight on turbine deck (one for two units), 4 on alternator deck, 2 at switchboard gallery, and about 8 spare on floor and in workshop. These with a station superintendent and a small technical office staff, constitute the day working force. In the winter an additional crew is required for cold weather



Lyons: Section Through 1,500 H.P. Francis Turbine Unit.

troubles. While Lyons is in Southern Europe, freezing weather is frequently experienced. In the winter of 1904-05 the thermometer went at times as low as 5 degrees Fahr. above zero; on which occasions the station experienced trouble from frazil ice. This had the serious result of occasioning several days' shut down. It is a question whether this ice is formed in the upper river, in the foothills of the Alps, or immediately at the station; the company's engineer inclines to the latter opinion and has tried many artifices to obviate the trouble, but without success. At the time of the wri'.'s visit, January 24th, 1906, the thermometer was dow. to about 15 degrees Fahr. and in anticipation of trouble, two 25 H.P. steam boilers on scows were supplying live steam at about 8 lbs. pressure to the

Clermont-Ferrand, General View.

covered forebays at the screens and sluice gates. To a Canadian in Southern France, in the heart of the silk country, this presented an interesting spectacle.

Transmission lines are entirely underground and consist of three wire cables, insulated with paper and armored with hemp lead and steel tape. The cable is laid directly in a trench on a layer of bricks and surrounded with gravel, which, owing to the low potential is found to provide ample insulation. Distribution lines vary in length up to 8 miles from the generating station, there being, of course, variable drops in voltage due to the different lengths, the adjustment of which has received considerable attention.

The power now in use amounts to about 14,000 H.P. at normal conditions. Of this, about 1,500 H.P. is traction load, 3,000 H.P. lighting load and the remainder mixed motor load. The tariff charged may prove interesting at this juncture for comparison with conditions in Ontario in view of the work of the Power Commission. Good quality steam coal at Lyons is about $4.25 per ton. The prices for motor power are as follows:—Up to 100 H.P. at 11½ cents per kilowatt hour; for over 100 H.P. at $34.00 per H.P. per year on a 12-hour basis, and $45.00 on a 24-hour basis. There is a sliding discount on the above prices as follows:—On a bill of $20.00 per month, 1 per cent.; on $50.00 per month, 2½ per cent.; on $100 per month, 5 per cent.; on $200 per month, 7½ per cent.; and on $300 per month, 10 per cent. For lighting, which the power company itself operates directly, the charges are as follows:—On meter system 13 cents per kilowatt hour for stores, hotels, cafes, etc.; 16 cents per kilowatt hour for houses. If on a flat basis the lighting rate is as follows:—For a 16 C.P. lamp, burning 750 hours, per year, $4.20; for 10 C.P., $3.75; for supplementary hours, add 6-10 cent for 16 C.P. and 4-10 cent for 10 C.P. for each hour. In the flat rate the bill is determined by a time meter.

Clermont-Ferrand, on the Sioule River.

Clermont-Ferrand, a small city of some 50,000 people. about 80 miles west of Lyons, has as yet but a small demand for lighting, traction and motor current. The hydro-electric plant recently built for its supply is, however, of interest, not only because of some of the constructive engineering features, but because it must come into competition with steam in the heart of a coal producing district.

The generating plant is situated about 20 miles west of the city, in a narrow valley at a high elevation. The available water from the river in continous flow is upwards of 2,000 cubic ft. per second under normal conditions; but by means of a storage reservoir the natural flow is increased during dry periods. The working head varies between 65

and 78 feet, depending upon the water level in the head (storage) reservoir. The head is secured by a dam in the gorge about 100 feet total height and 370 feet long on the crest, which is curved upstream; the dam is of concrete and contains about 50,000 cubic yards. The water thus im-

Lyons: Interior of Generating Station on the Rhone.

pounded forms a reservoir about 5 miles long and about ⅛ mile broad on the surface.

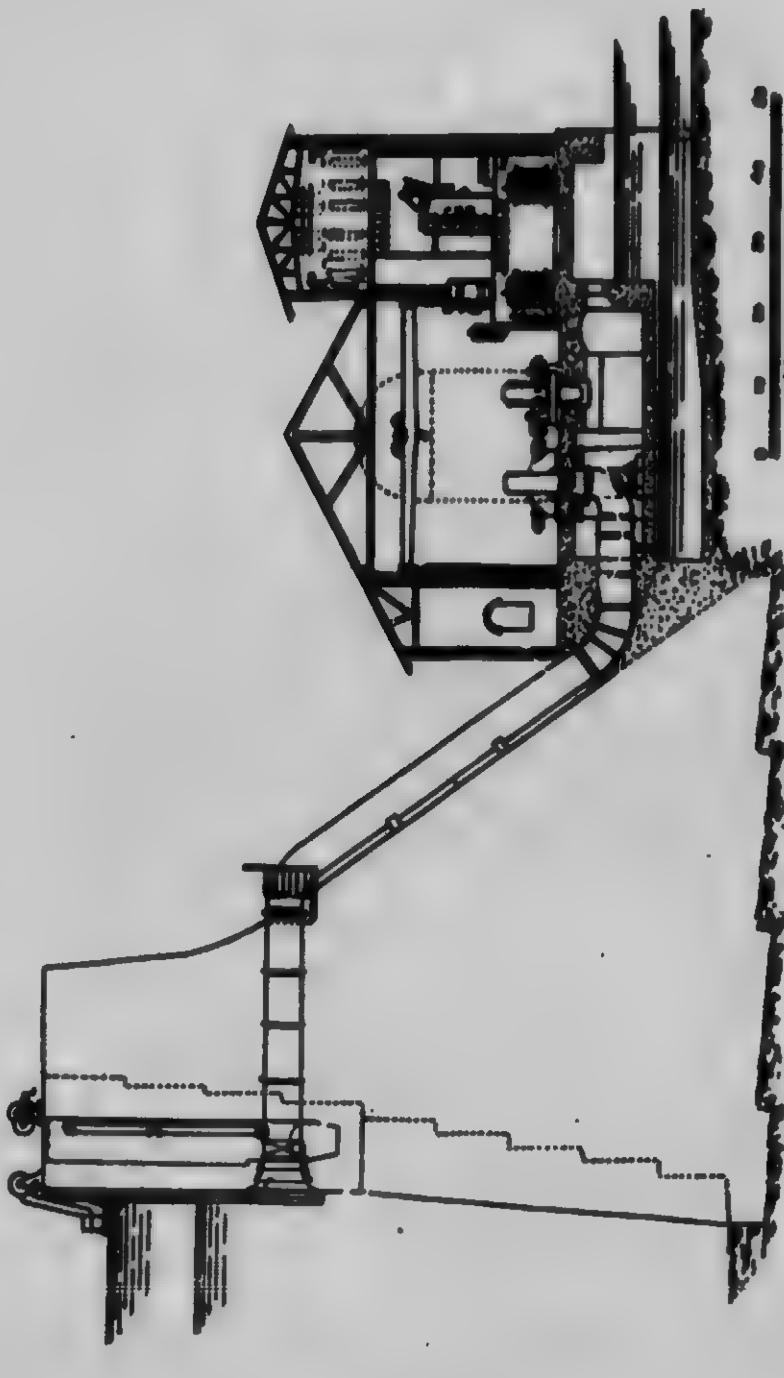
The power station is built as a part of the dam on the lower side, as shown in the sectional sketch, and the pen-

stocks, 5' 2" diameter, are carried through the dam proper directly from the reservoir without any intermediate forebay. The spillways for high water, are situated one at each end of the dam, either side of the power station.

The turbines are of horizontal shaft, double, spiral,

Transmission Line: Clermont-Ferrand, Railroad Crossing.

Francis type, directly connected to the generators, and have two draft tubes. They are rated at 1,200 H.P. under 65 ft. head (considerably too small for the capacity of the generators) and are said to attain an efficiency of 76 per cent. at



Clermont-Ferrand: Dam and Generating Station.

full and 80 per cent. at three-quarters load. The governors are of the same general type as at Lyons, with about the same refinement. All the hydraulic apparatus was constructed by Escher Wyss & Co.

The generators are three phase of 1,000 kilowatts capacity wound for 1,000 volts, at 50 cycles, and revolve at [illegible] R.P.M.; they are claimed to have an efficiency of 94 per cent. at full load. They are built and installed by the Societe Anonyme Westinghouse of Havre, who also supplied all other electrical apparatus. The station is designed for six units, but at the present time only three are installed, with two exciters.

Switchboards are arranged so as to operate the whole station in parallel, or so as to make any combinations of units, and in a general way, are identical with the latest practice of the Westinghouse Company. A feature of station detail, is the admirable isolation of circuits, and of other means of preventing shorts and maintaining continuous operation. The transformers from 1,000 to 2,000 volts are oil cooled 375 kilowatts each, with 97.7 per cent. efficiency at full load.

The transmission line about 20 miles in length, to Clermont-Ferrand, is of special interest, as illustrating some of the latest French practice. The pressure is 20,000 volts and the two circuits now erected with copper wires of 8 mm. are each designed to carry 2,500 kilowatts with a loss of about 7 per cent. The line follows a tolerably straight course over the mountains and is most substantially built with structural steel towers about 40 ft. high, set in concrete and normally spaced about 330 ft. apart. The insulators are carried on built steel framework and wires on one circuit are spaced about 34" apart, the circuits being separated so as to permit repairs on one while current is on the other. The insulators are of a special pattern similar to those used on the Paderno-Milan line, the main line being two-piece, six petticoat. At railroad crossings special wire cradles are erected, as shown in the accompanying view.

The main sub-station at Clermont-Ferrand, is a very substantial building, thoroughly fireproof, and is arranged with isolated circuits, the barriers being of reinforced concrete. The transformers step down to 3,000 volts for local line distribution.

At the present time the plant is generating about 1,500 kilowatts, of which about half is for lighting, and the remainder for factory motors. First quality steam coal in Clermont-Ferrand costs about $3.40 per ton. On a 12-hour day basis the Power Company sells, say 100 H.P., at about $33 per horse-power per year, and on a 24-hour day basis at about $42. The current is sold by meter on a progressive tariff, decreasing inversely as the amount used. Lighting current costs about 15 cents per kw. hour.

II.

FRENCH PLANTS IN THE VICINITY OF GRENOBLE.

The city of Grenoble lies in [illegible] heart of the French Alps. Its 70,000 people are engaged almost entirely in the manufacture of gloves and kindred leather industries, hats, buttons and clasps, linen and silk weaving, wood-working, paper, cement and miscellaneous iron manufactures. In earlier days, many of these industries were operated by small steam power units, and in the case of paper and cement, by direct water-power, at the waterfalls in the vicinity of the city.

Since the advent of electrical transmission, however, the conditions have changed; now the numerous waterfalls are

Fig. 1.—Avignonet Dam and Head Sluice.

more advantageously developed and their power transmitted to the city and adjoining towns. Grenoble is situated at the junction of two small rivers, the Drac and its tributary the Isere, both rich in natural power. A few miles above the city, on the Drac, another tributary the Romanche enters, and this, notwithstanding its small size, is the most efficiently worked of the three. On these rivers and within thirty miles of Grenoble are now installed some sixteen hydro-electric and direct hydraulic plants, varying in capacity under normal conditions, from 1,000 to 8,000 h[illegible]power, and having an aggregate power of some 60,00[illegible] [illegible]wer.

Under these circumstances, it is not su[illegible]g, that when a few years ago the French Government and the people took up the question of investigation of the water-

powers and hydro-electric resources in the Alps, Grenoble was chosen as the headquarters and centre of operations of the Congress. The work of this body, known as the "Congress de la Houille Blanche," ("White Coal") has now become world famous and its proceedings, bound in two large octavo volumes, form a most valuable engineering record, describing as they do in detail, the many plants then (1902) in operation and under construction.

The moving spirit of this Congress was M. Berges, of Lancey, a small town in the valley of the Isere, about 10 miles north of Grenoble. He owned several mills utilizing water-power from mountain streams tributary to the Isere, aggregating about 6,000 horse-power; used mainly for [illegible] and paper manufacture, saw mills, etc., as well as lighting and traction purposes. That he is a pioneer is evident from the fact that as early as 1868, he built the first conduit down the mountain and established a plant at Lancey, under a head of some 600 ft. A few years later, he increased this to

Fig. 2.—Avignonet Generating Station.

1,600 ft. head, using about 18 cubic ft. of water per second. This plant has continued in operation to the present time with but little trouble from the high head. A second installation here of about 2,000 ft. head remained until a few years ago the highest operated head in the world.

It is, of course, impossible in this article to adequately describe the many plants in the vicinity of Grenoble. Several of the more interesting installations are selected as typical of the district in which they are located.

Avignonet Station, Drac River.

The Drac River drains a large area in the higher Alps and flows to the Rhone. Its dry weather flow in midwinter is fed only by springs, and above its junction with the Romanche does not exceed 800 cubic ft. per second. At

times of freshet, however, this discharge runs up to the enormous flood of 40,000 cubic feet, a ratio of 1:90, which is [redacted]

The uppermost plant on this river at present is that of Avignonet, situated in a deep and narrow gorge about 25 miles above Grenoble. It is one of three plants owned by "La Societe Grenobloise de Force et Lumiere," and has an output under normal conditions of about 6,000 horse-power. The power is used in Grenoble for street railways and miscellaneous industries, for mines at La Mure, 8 miles away, and for factories at Bourgoin, 60 miles distant.

The general scheme of the plant is that of a dam in the gorge about 3,000 ft. above the station; a tunnel in rock, a forebay cut in the rocky cliff; and penstocks to a generating station in the bed of the gorge; the hydraulic units operating under about 80 ft. head.

Fig. 3.—Interior of Avignonet Station.

The dam is a heavy concrete structure of the over-fall type, with a total height of about 65 ft., having exposed faces lined with masonry. On one side is a sluice way closed by a Stony gate, about 25 ft. wide by 20 ft. deep. (See Fig. 1.) The dam is seldom over-topped by floods, the regulation being effected by the Stony gate. In front and shoreward of the sluice is the intake, with screens and headgates opening to head race, and being a tunnel, is protected from rock slides, and has a carrying capacity of about 1,400 cubic ft. per second. This tunnel has an overflow regulating weir which discharges into the river at about 200 yards above the station.

The tunnel terminates in a forebay formed in the cliff by excavation and heavy masonry walls, provided with an adjustable weir and spill, and with separate screens and

sluice gates to each penstock. The penstocks—five in number, with provision for two more—are 7 ft. diameter, and are fitted with 4 ft. diameter breathers below the sluice gates. See Fig 2, in which may be also noticed a light suspension bridge crossing the river at this point.

The generating station is a heavy stone structure, equipped with five units, each of about 1,200 horse-power electrical output, with horizontal shaft, direct connected, at 250 R.P.M. The turbines are double "American" type, built by Piccard Pictet & Co., of Geneva, and are fitted with oil pressure governors, which appear to give good regulation. The generators are by Schneider & Co., of Creusot, 3 phase —the latter being 15,000 volts. Three original units installed in 1901 were formerly wound to 26,000 volts, and intended to operate directly on the line without transformers; but these were found unsatisfactory, hence were rebuilt for 15,000 volts. The transformers are 15,000 to 26,000 volts, air cooled. The interior of the station is shown in Fig. 3.

The transmission line is interesting from the fact that the portion nearer to Grenoble is used jointly by this and another company (Champ Station, described below). The line from Avignonet to Grenoble consists of three circuits carried on iron poles. The towers for the joint transmission line shown on the right hand of Fig 4, are about 40 ft. high above ground, and carry six cicuits of 26,000 volts. These towers are set 6 ft. in the ground in concrete, the cross arms are wood, 10 ft. long, set in an iron framework, and each tower costs, complete, $100. At the junction with the second company, about 8 miles above Grenoble, a special structure (Fig. 4) is erected, and similar ones are also used in the city. Each company has its respective side and interconnecting and sectional switches. The two companies work in harmony, one using the other's wires at times for repair on the other side of the tower.

The snow seen in the accompanying pictures, while common, is unusual to such an extent in this locality. There is no trouble from floating or frazil ice, however, in any of the power plants in the vicinity of Grenoble.

Champ Installation, Drac River.

The Champ Station is situated near a village of the same name, and is about 8 miles above Grenoble, at the junction of the Romanche River. It is owned and operated by the Fure and Morge Co., of Grenoble, and under normal conditions of river has an output of about 6,000 horse-power, which is used for miscellaneous factory power in and near Grenoble. There are upwards of 70 works now connected through about 15 receiving stations. It was first operated in 1902.

The general scheme is quite different from the plant at Avignonet, owing to the nature of the river at this point,

which is shallow and flows through a gravel bottom in a wide valley. The intake works are situated about 3 miles up stream and the water is conveyed to the generating station by means of a flume laid underground; the station stands in the flat bed of the valley and the water is discharged through a short canal into the river channel near by.

Fig. 4.—Junction Tower, Transmission Line.

The intake consists of a submerged dam at right angles to the stream, terminating near the shore, in an intake set parallel to the stream, consisting of submerged arches provided with gratings and sluices. Special precautions were

required in this respect to prevent entrance of debris, gravel and stones, of which the river carries considerable. Behind the intake is a headbay 1,900 feet long, acting as a settling basin and provided with over-flows having adjustable crests. At the end is a bell-mouthed entrance to the flume, fitted with a gate having an air inlet behind.

This flume is a most interesting work, about 14,000 feet long, 10 ft. 8 in. interior diameter, laid on a grade to conform to the slope of the river, partly in trench cut, and then filled over with gravel and earth. Its carrying capacity is figured at about 800 cubic ft. per second at a speed of 10 ft. per second. The upper 6,000 ft. being under light pressure, is of concrete reinforced with steel rods. The girth rods, a few inches apart, vary from ½ to 1 in. diameter, and the longitudinal ones from ¼ to ½ in. The whole thickness of shell varies from about ¾ to 1¼ in. The remainder of the flume is of steel plate from ⅛ to ⅜ in. thick, and the structure throughout rests on a concrete foundation about 12 in. thick. There are three air shafts or breathers carried above the head level about 4 ft. diameter, along the length, to provide against entrained air or collapse when emptying. The most interesting feature of this flume is the terminal air shaft at the generating station, which consists of a vertical prolongation of the steel flume after the penstocks are taken off leading to the turbines. The vertical shaft converges from the 10 ft. diameter to about 5 ft. at the top, a total height above tail water of about 140 ft. The top terminates in an open chamber drained by three down pipes 18-in. diameter leading to outlets in the tail race. The water stands up to about 116 ft. above tail level when the plant is not operating, but when running full load this becomes 100 ft., which is the working head, the difference being friction and entry losses

Referring to Fig. 5, showing the stand pipe relief, a scaffold for repairs will be seen. It may be interesting to not that about three weeks before the writer's visit on February 13th, 1906, the upper part of the pipe collapsed from a singular cause. A few days of cold weather caused ice to form near the top with the water at a high level. Subsequently, when the water lowered suddenly, a vacuum was formed resulting in the crushing of the thin steel shell for about 20 ft. from the top. While this accident might happen in Canada, it is considered as a very unusual occurrence here.

The turbines, five in number are supplied by short horizontal penstocks connecting with the main flume, fitted with butterfly valves. They were built by Neyret-Brenier & Co., Grenoble, and are single wheels on horizontal shafts with cylinder gates, operating at 300 R.P.M. giving 1,500 horsepower. Though several wheels are fitted with simple governors they are regulated by hand, and appear to be fairly

steady. In addition to the stand pipe relief, there are automatic relief valves on each turbine, which are also fitted with hydraulic servo-motors operating the distributors and compensating valves, thus shunting the turbines and maintaining a nearly constant flow in the main flume. The

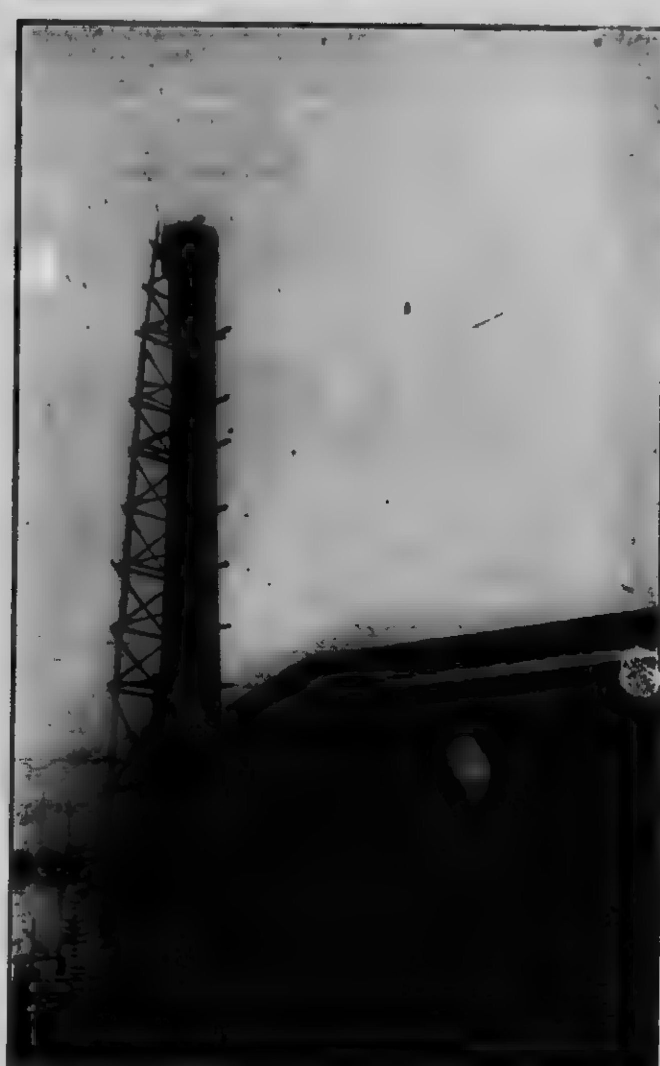


Fig. 5.—Terminal Overflow Pipe, Champ Station.

attendants say that the normal variation in level in the standpipe when operating is about 6 inches.

The generators are by Brown Boveri & Co., of Baden, 1,000 k.w revolving field 3,000 volts, direct connected, and with the switch-board and transformers from 3,000 to 26,000

volts, present no especial features. The transmission lines are described above.

Gavet Station, Romanche River.

The Romanche River has distinctive features which are remarkable. Its flow is very small, in dry weather being only about 300 cubic ft.; normal for about 9 months about 700 cubic ft., and flood discharge about 6,000 to 9,000 cubic ft. per second. Its descent is very rapid, hence high heads are the rule in the seven plants situated within the 12 miles of its course. These plants aggregate nearly 40,000 horse-power, and are used for various purposes; mainly in electro-chemical industry. There are several carbide of calcium works, and at Livet, 24 miles from Grenoble, is the celebrated electric steel works of Keller Leleux & Co. At Livet is located also the municipal plant, generating light and power current for Grenoble. The transmission line of the

Fig. 6.—Interior Gavet Station.

latter is unique, for it is constructed with wood-concrete poles, that is, thin straight cedar poles encased in an envelope of concrete from 1 to 2 in. thick, which in the three years of operation appear to have given entire satisfaction. A careful examination of these revealed no serious cracks and it has occurred to the writer they might he tried with success in Canada, notwithstanding the cold weather conditions.

The Gavet Station, just completed, is situated about 8 miles above the Champ Station, or 16 miles from Grenoble. It also is owned by the Societe Grenobloise de Force et Lumiere, and commenced operations about March 1st, 1906. There are now three units installed, with a total output of about 5,000 horse-power, and provision for doubling this capacity. The low water period of the river, however (about

3 months), gives only about this amount. The power will be used for manufacturing; both mechanical and chemical.

The headworks are very ingenious, and a type of all plants on this river, which floods quickly and carries large quantities of gravel, etc. The head dam consists of piers and buttresses carrying two steel Stony gates (counter-balanced), each about 30 ft. wide and 12 ft. deep, capable of being operated by hand by one man. In front of the dam is a weir parallel to the stream, with its crest about 2 ft. below the top of the gates; behind this is a settling basin having a sluice at the lower end and having a second similar weir on its opposite side. Water, after passing the first two weirs, enters a second elongated basin, having, at the lower end, a third sluice, and, in the side, the head screens leading to the head race, which is provided with a simple

Fig. 7.—Gavet; 2,000-H.P. Turbine.

gate about 12 ft. wide, 10 ft. deep. This scheme offers two Stony and two secondary sluices for normal flood water and permits the passage of abnormal floods over the whole; at the same time it provides settling or catchment basins for gravel. The flume to the generating station consists of a tunnel driven in the rock cliff about 10 ft. square and 7,000 ft. long.

The tunnel terminates in a small covered forebay high up the face of the cliff above the station, having outlets for two penstocks and one spillway. The penstocks—one of which is no[illegible]lled—follo[illegible] down the cliff, and are 7 ft. diameter by [illegible] 500 ft. long, and each branches to the three main and [illegible]o exciter units at the rear wall of the station.

The station is of rubble stone, having a generating room, commodious switch-board gallery, wire ducts, transformer and arrester rooms. The writer had the pleasure of visiting the plant on February 14th with the consulting engineer, M. Boissonas, of Geneva, who pointed out many of the new features. On this occasion the units were started on their first long run, for the purpose of drying out the generators and transformers.

Each turbine develops 2,000 horse-power working under a head of 190 ft., and they are of the horizontal shaft, single spiral Francis type, built by Piccard Pictet & Co., of Geneva. The distributor gates are swivel style, with an actuating gate ring carried on arms fitted with springs, to positively take up lost motion. The governors are by the same makers, arranged with a new device on the fly balls, to stop petty vibrations. The main shafts have fly wheels (see Fig. 6) and Zodel flexible leather link couplings.

The generators are by Schneider & Co., Champagne, revolving field type, three phase, 4,000 volts, 231 amp. per phase. The transformers step up to 26,000 line voltage the same as at Avignonet, with which this station will at times be run in parallel, 24 miles distant. The line is at present carried on wooden poles.

Power Prices in Grenoble.

Good quality steam coal in Grenoble costs about $5 per ton. The two power companies in the field sell for about the same prices. Those of the Societe Grenobloise are, in general, as follows:—For 24 hours service the average prices (variable on account of distance) are, say for 100 horse-power, $30 per horse-power year, and for 500 horse-power about $26 per horse-power year. In 500 horse-power quantities prices run down as low as $18 for transmitted power and even to $12 at the station. This company has now 15-year contracts for about 15,000 horse-power, with some customers 100 miles distant (by line). In the case of the Champ Company selling upwards of 4,000 horse-power, the average price per horse-power of the output is about $25 on a 12-hour day and $30 on a 24-hour day. Lighting current, sold in Grenoble by the city plant, costs about 12 cents per k.w. hour.

III.

ITALIAN INSTALLATIONS NEAR MILAN.

That Milan is one of the most prosperous and enterprising of European cities is well known. It is the centre of the great plain of Lombardy, which for centuries has been famous for its wealth in agricultural products and dependent industries. The city has always been the commercial metropolis of Northern Italy, and is now the emporium of all Italy, just as Genoa is the national seaport.

To describe the industries of Milan would require a lengthy enumeration of nearly all branches of commerce and manufacture; and the long list would, without a doubt, represent a greater diversity of interests than any American city of like size, and even larger population. The proximity

Fig. 1.—Paderno: General View of Station.

of Milan to the Alps on the north and availability of economical electric power from hydraulic plants situated within transmission distance of the city has had the natural result of stimulating industry and establishing numerous factories.

The first application of electrically transmitted power was, of course, to lighting and traction, and for this purpose the pioneer company, "Societa Generale Italiana Edison di Elettricita," constructed and commenced operating a hydraulic plant at Paderno, on the Adda River, twenty-five miles north-east of the city. This was in 1898, but the same company had already a steam plant in Milan dating from 1883, with railway and lighting franchises. After the installation of the hydraulic plant, motor power for manufacturing purposes came gradually into great demand, with the result that this company not only extended its original hydraulic and auxiliary steam plants, but, with partially

allied companies, has recently installed several other hydro-electric generating stations, with which the Paderno and steam stations run at times in parallel. These new stations are Zogno, 40 miles distant north-east, which commenced operation about January 1, 1905; Vigevano, 20 miles south-west, commenced operation January 15, 1906, and Trezzo, 20 miles east, which will commence in the summer of 1906. The plants of these companies supply not only the city of Milan, but groups of large towns lying to the east and north, such as Monza, Brianza, etc., aggregating some 35,000 h.p. The second group of plants is that owned and operated by the "Societa Lombarda per Distribuzione di Energia Elettrica," which came first into the field with its plant at Vizzola, 30 miles north-west of Milan, in 1901, and later with a smaller one at Turbigo, 25 miles west in 1905, aggregating about 25,000 h.p. The latter, however, is not sent to Milan, but is distributed to numerous small cities to the north and west.

As examples of the hydraulic installations in the vicinity of Milan, the two large plants of the parent groups are chosen in this article as representing the practice in construction. In some respects these two developments are similar, but each has special features of interest. Viewed from the American standpoint, the substantiability and ponderous construction of each is most noteworthy.

The Paderno Station, Adda River.

The Adda River is the outlet from Lake Como, which is supplied by glacier-fed streams from the Alps. At Paderno which is about 15 miles from the lake, the river is in a broad, winding valley, and has such a fall as to produce a head of about 90 feet in a distance of a mile and a half. The flow of the river varies between 2,000 cubic feet per second and a flood discharge of, perhaps, ten times as much.

At the head works, a previous river regulation system, some 200 years old, was partially utilized in securing an adequate supply of water, and, with the reconstruction of earth embankments and the introduction of a needle weir with adjustable crest, a maximum supply of 1,600 cubic feet per second was ensured. Below this is a series of basins and short canals, one of which is navigable for shallow draft, and, after passing a headgate, the water for the station is carried by means of tunnel and cutting about 7,500 feet to the forebay on the hillside, above the station. The forebay or receiving basin, shown on the left of Fig. 1, is a heavy masonry chamber, in which the velocity of water, after 8 feet per second in the tunnels, is reduced to about 3 feet. At one end of the basin is a weir discharging to a waste-way, consisting of a flight of colossal masonry steps,

95 feet high and 90 feet wide, down which surplus water spills to the Adda, alongside the station.

The seven penstocks, 7 feet in diameter, discharge from the bottom of the forebay, each having a separate bay, closed with a sluice gate and protected by screens; they are carried down at an incline to the station rear wall, a

Fig. 2.—Paderno: Turbine Governor.

length of 205 feet and, entering under the floor, are fitted with butterfly valves just before connection to the wheel cases.

Seven main units, each of 2,200 h.p., under the normal head of 94 feet, constitute the power installation. Each

unit consists of a single reaction turbine, made by Riva, Monneret & Co., of Milan, and a 1,500 kw. three-phase alternator by Brown, Boveri & Co., of Baden, directly connected, on horizontal shaft, at [illegible] r.p.m. The turbine runners are "American" type, having inward or radial admission, with register gates and axial discharge. The governors, shown in Fig. 2, are operated automatically by water pressure from direct acting pumps, and give close regulation. The generators are wound for 14,000 volts at 42 cycles, and work through the switchboard to the transmission directly, without transformers. In the days when this electrical equipment was installed the high generating tension was a new departure, but there never has been trouble from such cause; and, indeed, the paralleling of this with the steam station at Milan and with other hydraulic

Fig. 3—Paderno: Interior of Generating Station.

plants is frequently accomplished without incident. Fig. 3 is an interior view of the station, showing generators and switchboard gallery.

The transmission lines of the Paderno plant have become noteworthy in electrical engineering, as they were the first in Europe using metallic poles with high tension. All the fears then expressed have proven groundless, and this line, traversing a region where storms are violent, has been remarkably free from troubles. In the light of transmission practice of the present day, however, with tensions three and four times that of Paderno, much that has been learned from this pioneer European work is now eclipsed by American practice. The line towers, with a roadway crossing "cradle," are shown in Fig. 4. The insulators used, though frequently illustrated, still remain a standard, and may be of added interest herein. (See Fig. 5.) The main line to Milan, 25 miles long, is in duplicate, carrying six

circuits on two lines of towers nine feet apart, and spaced about 35 feet high above ground, and are set in concrete. Railroad crossings are elaborate, consisting of veritable structural steel bridges, very substantial, but very unsightly.

As before noted, this company owns and operates the city and suburban electric railways and lighting systems,

Fig. 4.—Paderno: Transmission Line, showing a Roadway Crossing.

and a visitor to Milan cannot but be struck by the admirable modern methods everywhere in operation, especially in the street railway. In 1904 the company had some 100 miles of track, w[illegible] 425 cars; also 2,500 arc and 190,000 incan-

descent lamps. In motors for general use in and around Milan they sold about 21,000 h.p. to 3,600 motors. The prices obtained are approximately as follows: In Milan, depending on use, amount and distance from a minimum of 2 cents to a maximum of 8 cents per kilowatt hour for the use of 1,000 hours or less per year; for large powers, for, say, 6,000 hours per year, the price is as low as 1 cent per kw. hour. The price of steam coal in Milan is about $7 per ton.

The Vizzola Plant, Ticino River.

In a similar manner to the Adda River, the Ticino drains Lake Maggiore, another of the beautiful Italian lakes, and in its course to the River Po is rich in valuable water-power, which is being gradually developed. The Vizzola plant is only about ten miles from the lake, and is situated on the north side of the valley, in such a manner as to have an intake common with that of a navigation and irrigation canal, on the banks of which the station is situated.

This plant differs from Paderno in that it supplies many independent towns and works widely separated from each

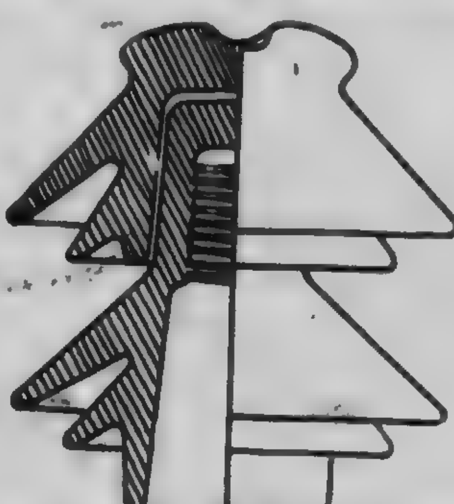


Fig. 5.—Paderno: Standard Line Insulator.

other. These works consist mainly of silk, cotton, and fabric mills, which had previously been operated by steam, or low-head direct hydraulic installations. The generating station is situated 30 miles north-west of Milan by railroad and road, but the main transmission lines, which form a network in the surrounding cities, notably Gallarate, Legnano, Busto Arsizio, and Saronno, vary in length from 10 to 30 miles. The total output is about 20,000 h.p.

The common head canal is about 3½ miles long, winding

along the edge of the valley until arriving at a deep cut near the station, where it separates into three outlets, one to the power station, a middle course to a series of three locks down to the Ticino River at tail-race level, and a third following the valley for navigation.

That portion of water required for the power station, amounting to about 2,200 cubic feet per second normal, is

Fig. 6.—Vizzola: Side Elevation of Aqueduct.

conveyed by means of an aqueduct to an elevated forebay above the station, whence by inclined penstocks it is led in the usual manner to the turbines. The elevated concrete aqueduct and forebay, or receiving basin, constitutes the

principal feature of this installation. As shown in Fig. 7, the aqueduct is a massive structure, a monolith of concrete, about 700 feet long, passing over a former depression, and carried on arches of 16 feet span, 36 inches thick at crown. The waterway is 22 feet wide and 12 feet deep, of trapesoidal section, having sides on a batter of 1:4, and the surface of water is about 35 feet above the graded ground level. The whole structure is supported on a pile foundation; this fact, together with the feature of unequal expansion in the aqueduct and adjoining forebay, a total length of 1,000 feet, involved special design to secure tightness and stability, and the subject was consequently most carefully studied. The whole mass, consisting of some 25,000 cubic yards of material, was made of concrete, laid in cement, in order to minimize shrinkage; and the laying of concrete was not unduly hurried. In addition, an envelope

Fig. 7.—Vizzola: Aqueduct, Receiving Basin and Gate-house.

of three thicknesses of tarred felt was interposed in the concrete forming the waterway at a distance of 12 inches back from the entire wetted surface. Except a few minor cracks, hard to detect by the eye, this work appears to be perfectly sound and tight. Fig. 6, side elevation of the aqueduct, shows the general character of the structure, and is from a photograph taken by the writer at the only point where a crack was plainly visible, as may be noticed by the traces of plaster caulking above the crown of the arch; this, too, was on a cold February day (1906), with the thermometer at freezing point.

The forebay structure is of the same character and general design as the aqueduct, having on the one side the screen and gate-house, over the entrances to the penstocks, and on the other, an over-flow regulating weir, permitting

spill of surplus water into a basin, which in turn discharges into the lower river level alongside the three canal locks above referred to. This is shown in Fig. 7, the generating station being on the opposite side of the gate-house, below the hill. The over-flow weir is 300 feet long, and, at a lower level, are also three sluice-gates for additional discharge. Twelve bays, each with a submerged arch opening, protected by screens, and capable of being closed by vertical sluice-gates, operated by either electrical or hand power, lead to the twelve penstocks. Ten penstocks for power units are 6 feet, 6 inches in diameter; and two for the exciter units are 3 feet; all are 150 feet long to inside of station wall.

The generating station (see Fig. 8) is a massive but plain building of concrete and stone, and the tail-race (on the right) excavated along its front leads to the low-level navigation canal. The power installation consists of ten 2,100 H.P. turbines, connected directly with horizontal shafts to 1,500 kw. alternators, together with two separately driven exciters.

Fig. 8.—Vizzola: Generating Station.

Under high and low conditions of river, the working head varies from 80 to 94 feet, respectively; with the normal at 92 feet. Of the 10 turbines, 8 are built by Riva, Monneret & Co., of Milan, and 2 by Voith, of Heidenheim, Germany. Both types are similar, with double runners and distributors, actuated by balanced gate-rings connected to swivel gates. The governors are water pressure type. The generators are by Schuckert, of Nuremburg, revolving field, three-phase, at 187 r.p.m., wound to 11,000 volts at 50 cycles; they work directly on the lines without step-up transformers.

Each large centre of distribution has its own separate transmission line from the generating station, which, while

expensive, has proved most satisfactory in convenience of operation, continuity and safety. Lighting current lines are also separate from the power lines. Nearly all the main lines have steel towers, with triple porcelain insulators.

The prices obtained by this company in the widely separated centres of consumption are based on a flat rate, and on a 24-hour day, average about $31 per H.P. year, with a minimum of $23 and a maximum of $44, depending on distance. The price of coal is about the same as in the city of Milan.

IV.

LATEST ITALIAN PLANTS IN VICINITY OF MILAN.

The city of Milan—the electrical city of Central Europe—is daily making fresh demands for electric power. This increasing demand has of late years been far ahead of the actual supply, with the result that the electric companies in the field are using every means to increase their output, are constantly seeking methods of extension and are, as well, exploiting new hydro-developments.

The general situation in Milan with regard to the supply and demand for electric current has already been described in a previous article. While the lighting and traction demands are increasing at a rapid rate, the greatest activity

Fig. 1.—Vigevano, Forebay and Gates.

exists in the market for mixed motor load for manufacturing purposes. As previously outlined, not only have the parent electric companies built new generating works adjacent to the pioneer stations at Paderno and Vizzola, but new groups of stations have been constructed by an independent company whose interests are, however, closely allied with those of Paderno.

The new company, the "Societa Conti per Imprese Eletriche" so called from the name of its energetic founder, Signor Ettore Conti placed in operation in January, 1906, one of its most modern plants, situated at Vigevano, 20 miles west of Milan. The original Paderno company, the "Societa Italiana Edison di Elettricita" has also placed in operation (April last) a second station, located at Trezzo, about 15 miles east of Milan. These two stations, the

newest additions to the Milan group, are described below, because they illustrate the latest types adopted by Italian engineers: hence, should be of general interest.

Vigevano on the Tessin.

The vicinity of Vigevano is not exactly one in which a hydraulic installation would be expected, as it is well down in the plain of Lombardy. The Tessin River, however, sweeping down from the Alps, winds through the country between great gravel banks, and has a very considerable fall. It has, for several centuries, paid toll to the millers along its course, and it is an interesting study in hydraulic evolution to examine the many ingenious water-motors of 20 and 30 H.P. built by the descendants of Leonardo da Vinci. It was in this region, and further north of Milan, that this great engineer and painter labored four centuries ago. "Labor" is a suitable word as applied to the old "Master," because

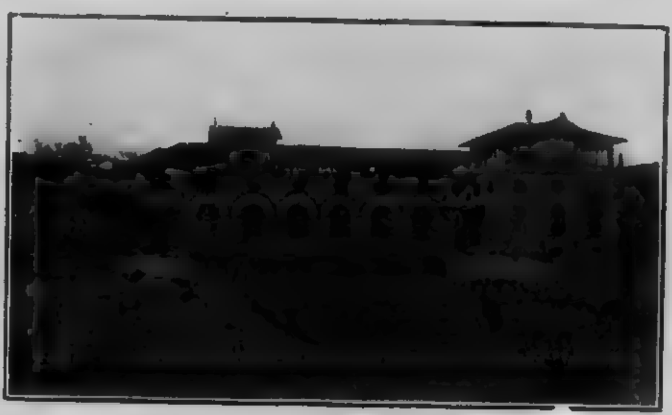


Fig 2.—Vigevano, Exterior of Generating Station.

even as an artist alone, he evidently had a tremendous capacity for hard work. Recently new light has been thrown on his work by the discovery in Milan, of many documents, sketches and papers, which show him to have been the rival of Michael Angelo in constructive activity and ability. It can now be said, that Leonardo da Vinci was the father of hydraulic engineering, just as Volta was the father of electricity.

A pleasing incident in this connection occurred at Glasgow on July 2nd last, on the occasion of the visit of the foreign electrical engineers, as the guests of the Institution of Electrical Engineers. The Italian section, consisting of forty members, headed by Signor Semenza, of Milan, presented Lord Kelvin with two ponderous volumes of photographs of sketches and notes made by Leonardo da Vinci. There were upwards of 1,500 photos, each about quarto

size, made from the leaves of Leonardo's note books, etc., found two years ago in an attic in Milan; fortunately in a good state of preservation, after 400 years. An examination of these sketches reveals some remarkable things concerning the engineering of those days; particularly in connection with the canals for navigation and irrigation in Lombardy, upon which Leonardo was engaged for many years. His work in many instances stands to this day, and is still in operation. His applications of water-power by rude impulse and even reaction wheels are most ingenious, and it will be of special interest to Canadians to learn that he is now credited with being the first designer and constructor of locks on navigation canals.

To return to the Vigevano plant, it may be said to be designed in a manner generally similar to that at Vizzola, already described. The water is taken from the river about 3 miles above the station, and is brought down in a canal cut

Fig. 3.—Vigevano, Interior of Station.

in the side hill of the river bank, which in itself is a large engineering proposition. The formation width of the canal bed is 15'-0", slopes 1:1, with gravel concrete lining and a depth of water of 12'-0": in embankment the outside bank is 15'-0" top width and the outside slope 1½:1, planted with small shrubs 18" apart. The velocity will be about 6'-0" per second. At intervals, overflow weirs and sluices are placed for regulation. On one of the latter an interesting work worthy of note was seen, consisting of an aqueduct 24'-0" span across another canal, with an interior section of 36" width, and 28" depth: this was of granite and each side consisted of one slab of granite 12" wide, 36" deep and 28'-0" long, set on edge; the bottom of the waterway being formed of 4" slabs.

The canal terminates in a forebay, having 12'-0" depth of water with an overflow weir on the side opposite the en-

trance, shown in foreground of Fig. No. 1. The screens are parallel to the canal, 110'-0" long on the face and in 8'-0" minimum depth of water, with 1" spaces. Water, after passing through the screens, is controlled by 2 sluices in each bay, and flows into a pit 18'-0" deep, from which the penstock carries it to the station. Surplus water passes automatically over the weir and down a spillway consisting of a flight of six great steps, leading to the tail races, see on left of Fig. 2, which shows exterior of station.

The penstocks, 6'-6" diameter, pass down to the power house on a slope of about 30 degrees, leading through the rear wall above the turbines, and turn down vertically to the tops of the wheel cases. Special provision is made against expansion thrust by placing large abutments outside the wall in which to anchor the pipes. After passing through the turbines, the water is carried through tail pits consisting of arched races in the foundations; it is to be noted that here, as everywhere in European plants, pro-

Fig. 4.—Vigevano, Hydraulic Unit with Governor.

vision is made for closing off each pit from the main tail race for repairs, so that each may be isolated.

As a generating station, the arrangement at this plant is ideal, and, upon entering, the visitor is impressed with the convenient and roomy arrangement. (See Fig. 3.) The turbine and generator units, five in number, are arranged abreast in a long hall, the two exciter units being at one end. At the same end is the switchboard, mounted on, and under, a floor, which is 6'-0" above the main floor; the whole hall is about 340'-00" x 40'-0". Alongside the gallery is an enlarged wing, shown on the right of Fig. 2, containing all switching and transforming apparatus, the arrangement of which in convenient sequence, roomy spacing and isolation is very clever. In the introduction of these features the European practice in design within the past two years is quite marked.

The turbines are by Riva Monneret & Company, Milan, four units being installed at the time of the writer's visit on February 6th, 1906, and one being still in the shops. The type is horizontal shaft double Francis inward discharge, into a draft chest: the cases are exposed and form the termination of the penstocks. See Fig. 4 for details. Each turbine unit works under a head of 61'-0", developing 1,400 H.P., using 270 cubic ft. of water per second. The governors are of a special oil type, recently perfected by the turbine makers, sensitive and very powerful for their size; the writer looked at the governors, especially to discover periodic hunting while the station was running in parallel with a steam plant at Milan, but could see no injurious irregularities. The generators by Gadda & Company, Milan, are directly connected, 3-phase, wound to 2,750 volts at 42 cycles.

Switch gear is fitted with table type instruments and distant control apparatus, so that the operators can at once

Fig. 5.—Trezzo, Dam with Collapsible Crest.

see both instruments and machines. Current is stepped up to 25,000 volts and the transmission lines, comprising two circuits of 7MM. wires are carried in steel towers spaced 350'-0" apart.

The power from this station is used in outlying towns to the north and west of Milan, as well as in the city, and the loads and prices are about the same as those indicated in the previous article in the same locality.

Trezzo On the Adda.

The Trezzo plant, used in conjunction with the Paderno station, introduces entirely new features in the Milan hydraulic types. The Adda River at this point (5 miles below Paderno) makes a horseshoe bend around a rocky hill and at the same time has a rapid fall. The power project consisted of damming the river at the crown of the

bend, and placing a power house alongside the rock cliff, discharging the water from the tail races through tunnels, under the hill, to the river below. The low head thus obtained only 24'-0", required vertical shaft type of units, with low speeds and a corresponding large volume of water, with many units.

The construction of the dam was a very delicate operation, owing to the rise, and peculiar violence of the river after rains in the mountains, 30 miles distant. The foundations of the whole structure are of concrete, laid on the rock river bed, and, in the main portion, consist of large terraced courses of monolithic concrete, over which the water can discharge in high seasons. The upper part of this work consists of an adjustable crest formed by structural steel bents, provided with removable wooden sheeting and planking capable of raising the water to an elevation

Fig. 6.—Trezzo, Spillway Sluices.

about 10'-0" higher than the permanent concrete crest, thus forming a huge flash board system.

This is shown in Fig. 5, from a photo taken on the writer's visit, May 24th—after the plant had been running about six weeks. At the opposite (down stream) end of the dam, a set of three spillway sluices is located (see Fig. 6), having vertical sliding gates operated by hand, permitting water to pass beneath; about 2,000 cubic feet per second was passing through at the time the photo was taken. In the foreground will be noticed a cave-in of the rip-rap retaining wall. While not discernible in the illustration, it is interesting to note that repairs to this were under way by means of a new system, recently introduced in France, of making bags or cylindrical nets of galvanized iron wire fence netting, filling these with stones and small boulders, and rolling or placing them in a suitable position to form a new wall.

Against the high cliff of the river, in the horseshoe, the power house was constructed, having its face parallel to the river flow opposite, yet almost square against the current on the approach to the curve; this arrangement provides ample water with minimum deflection, and at the same time produces a sweeping current to carry past debris, etc. The station shown in Fig 7 is situated about 300 yards up stream from the sluice gates, and is a large and very handsome structure built entirely of stone. The stones are left rock face, but are hewn roughly to courses, and are obtained from the cliff alongside, which is formed of a peculiar cemented gravel, resembling a thoroughly mixed hard gravel concrete. The stones after slight dressing give a very pleasing effect, which many architects would strive hard to obtain in concrete by artificial means.

It will be seen in the illustration that there are ten main water entrances, each 22'-0" wide, and two exciter in-

Fig. 7.—Trezzo, Exterior of Generating Station.

lets. These represent as many units and the water in each, after passing screens and gates, enters a wheel pit with its vertical turbine, thence into the tail pit and common bay, about 300 x 60'-0", in the rear of the station. From this point the water is conveyed by means of two tunnels beneath the cliff to the lower river. For a distance of 150'-0" above the station and in continuation of the face of the water inlets, a series of 10 overflow weirs is arranged to take care of slight inequalities in the river level.

The vertical turbines are Francis type, each of 1,500 H.P. capacity at 105 R.P.M.; the first six and the two exciter units are by Riva Monneret & Company, and the seventh is by Escher, Wyss & Company, of Zurich. Considerable use has been made of re-inforcing steel in the concrete foundations and settings of these machines. The governors are connected by two stems to the gates. In general arrangement (see Fig 9), the power units are

similar to those at Lyons already described. The generators are of 3-phase revolving field type, two at 50 cycles, and the remainder at 42 cycles, and are built by Gadda & Company, Milan.

In the arrangement of switches, transformers, arresters, instrument boards, control, etc., this station is, if possible, more complete and roomy than that at Vigevano, and the whole large wing at the end of the station is occupied by this apparatus. The distant control apparatus is, in itself, a very perfect arrangement, permitting complete operation from table switchboard to isolated apparatus in different compartments of switch and transformer rooms.

Four transmission circuits, three to Milan and one to Bergamo are now in operation at 13,000 volts, carried on structural steel towers known as the "Elastic" type. The function of these towers is that while rigid at right angles they will oscillate slightly in the direction of the line,

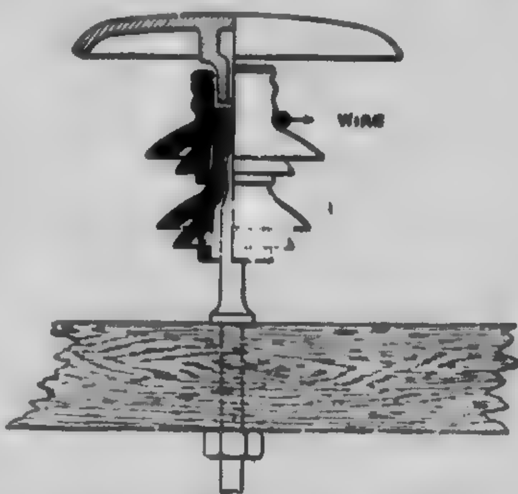


Fig. 8.—Semenza Umbrella Type of Insulator.

creeping of the cables being prevented by guying at intervals. These towers are 40' high above ground, built with two legs (channel section) 7'-0" apart, and each leg set in concrete 5'-0" deep; the top of each leg member carries two circuits. Insulators on these lines are of the Paderno type, but are being partially replaced with a new design recently patented by Signor Semenza, consulting engineer of the company. This is a radical departure, but most simple, with qualities of insulation which are obvious. The design, which can be better illustrated (Fig 8) than described, consists of the lower portion of a simple Paderno insulator, provided with a threaded top and side groove in which the wire passes: over the top is screwed an "umbrella" made of terra cotta about 12" in diameter, having a small watershed arranged on each side above the wire.

It is interesting to know that in the break-down tests on an insulator designed for 30,000 volts, the ratio between wet and dry conditions is nearly unity, viz.: 122,000 volts for dry and 110,000 volts for wet. A feature of this new type is its small cost, the expensive, large upper

Fig. 9.—Trezzo, Interior of Station.

part of the usual porcelain insulator being replaced by a simple, easily formed piece of terra cotta or other cheap material. As jokingly pointed out by Sig. Semenza, a new umbrella is, in this case, cheaper than an extra petticoat.

V.

ITALIAN PLANTS AT ROME AND NAPLES.

[redacted]

To write of modern twentieth century electric power installations in the ancient city of Rome, seems almost a romance; but like the ancient city, which was ever seeking new things; modern Rome has risen to the requirements of the present age, and is evidently determined not to lag behind the rest of the world—in which at one time she reigned supreme. It is quite true, that Rome has one of the largest hydro-electric plants in Europe; that she has a most modern electric lighting system; and that she has hundreds of up-to-date electric cars—veritable hill climbers—traversing her narrow streets, crowding across her fountain splashed squares, and clanging past the grim Colosseum, the silent Forum and radiant St. Peter's.

As a user of electric power, Rome has but little demand beyond lighting and traction. Notwithstanding her population of 450,000 there are few factories, and most of the power used in motors is in very small units. The lighting and traction using about 10,000, and 4,000 H.P., respectively, form almost 90 per cent. of the total requirements. One company, the "Societa Anglo-Romana" operates the gas, electric light, and traction systems; for all of which it has a monopoly until 1928. Previous to 1892 all electrical energy used in Rome, was generated by steam as the motive power; but subsequently a small hydraulic plant at Tivoli, eighteen miles east of Rome, was constructed and operated by the company. In 1900, a modern hyro-electric power plant, on the same site, was completed and commenced operations; while in 1902 this plant was extended to its present capacity, viz., a minimum of 12,000 H.P. In addition to this, the company still operates two steam plants at Rome having 5,000 H.P. By the present autumn, the same company will have in operation a second hydro-electric plant at Subiaco, about 35 miles east of Rome, generating 5,000 H.P. under 225 ft. head, with three-phase generators of novel pattern, wound to 30,000 volts, thus not requiring transformation for [redacted]

The falls of Tivoli are at the base of the Sabine Hills, and are formed by the Anio which here passes through a romantic ravine, having a fall of 360 ft., and an aggregate of some 530 ft. within two miles. Great engineering works were constructed at and around these falls by the ancients, also in the beginning of the last century; when, owing to destructive floods, at and above the town, new relieving spill

Fig. 1.—Tivoli Station: Penstocks for Francis Turbines.

tunnels were driven. For centuries, a considerable manufacturing community has existed at these falls, operating its mills by water-power, with wheels of all descriptions. The town itself has still several paper mills, but its manufacturing interests are small.

The hydro-electric plant is situated in the gorge where it debouches into the wide valley. It is situated beneath the famous Villa d' Este, 300 years old, one of the most beautiful gardens of Italy, and is within a few minutes of Hadrian's Villa, the greatest of ancient royal homes.

Water is brought to the forebays on both sides of the river, high up on the cliffs. The older waterway is by means of ancient canals on the town side; the new one on the opposite side consisting of a canal a mile long. Water obtained by the older canals, provides two heads of 530 and 346 ft., from different points, while the newer system gives only 165 ft., being obtained by a dam built in the gorge above the lower cascades of the falls. The dam is of

Fig. 2.—Tivoli Station: Hydraulic, Penstock Gate Valves.

masonry, built on rock foundation, arched up stream in plan to a radius of 280 ft., and has a crest length of 240 ft. It is 50 ft. high, of overfall ogee type, having a width of 12 ft. on top, and 45 ft. on the base. The new canal has a capacity of 350 cubic feet per second, and terminates in a forebay 120 x 110 ft. and 19 ft. deep, divided into two parts by a wall with submerged arches, to assist in obstructing debris.

Penstocks built at different times under the various heads are 3'-0", 5'-0", and 4'-4" diameter, respectively. Of these the first serves two units, the second, three; and the third set (three in number) serve one unit each—see Fig. 1. They are built of steel plate, with inside and outside lap rings. The three new penstocks are made of 5/16" plates at the top, and 7/16" at the lower end; while for the 80 ft. spans across the river, they are ¾" plates, and double rivet-

ed. In addition to gates at the forebay, each penstock has a gate valve before connection to the turbine, operated hydraulically. (See Fig. 2.)

The substantial construction of these works is indicated in the method of carrying the penstocks down the river bank, a most generous expenditure of heavy masonry, ornamental bridges, stairways and portals, which would appal American investors. The bridging of the river, however, by the penstocks, without auxiliary support is an example of the utilitarian side of European engineering, instances of which one meets every day alongside the aesthetic features. This leads one to consider whether in newer America, where all is utility we do not too often entirely forget the aesthetic. Are we not also sometimes inclined to reduce our substantiability in design to a minimum, in our desire to be economical, and in our effort to rush through what might be termed semi-temporary construction in order to secure quicker financial returns?

In the generating station, which is of stone masonry, are seven power units on horizontal shafts, four of which were installed in the first construction, under the higher heads, using Girard turbines, and three in the extension installation using Francis type turbines. These are arranged in a long central hall (see Fig. 3) having the penstocks and tail race on one side and the switchboards and offices, etc., on the other.

All the turbines are built by Ganz & Co., of Buda-Pesth, and are nominally of about 3,500 H.P. each. The Francis type installed in 1902, are examples of a system frequently built by this company, and, while generally similar to most turbines of this class now manufactured in European shops, have the distinction of being regulated by gates in the draft tube, on the lower side of the runner. This type is not a novelty, there being several similar installations both in Europe and America, but the arrangement is sufficiently out of the ordinary to merit special description. Referring to Fig. 4, which shows a vertical section of the turbine through the shaft, the following are explanatory notes:—

K—The cast iron wheel case "Snail Shell" type for incoming water, connected to penstock.

S—Distributor between case and runner, fixed vanes.

R—Runner, Francis vanes, attached on end of main shaft Y.

O—Draft tube.

A—Governor centrifugal regulating fly-wheel, "Hartung" type.

B—Dash pot with glycerine, to regulate oscillations.

C—Connections to governing valves, servo-motor, and hydraulic governing relay.

N—Adjustable fulcrum for controlling lever Z.

U—Cylinder connected to Servo-motor for actuating piston of gate stem X.

X—Gate stem attached to cylindrical gate.

Q.—Cylindrical gate piston, reciprocating horizontally, to open or close outlet from runner R. Diagram shows gate wide open.

The same general principle is used on the Girard units, but, owing to the nature of the turbines, which are outward discharge, the gate operating mechanism is differently applied. All these units are connected in parallel with conspicuous success; results, all the more remarkable, because of two types of turbine operating under three different heads, and having a transmission line with mixed and extremely varying load.

The generators are 3,300 K.W. rated capacity at 10,000 volts, three phase revolving field type, each having its ex-

Fig. 3.—Tivoli Station: Interior.

citer carried on the outboard end of the main shaft. The internal diameter of the armature is 13 ft. and the inductor weighs 24 tons. While the units are three phase, they are operated about half the time as mono-phase; on account of a large single phase distribution system, which had existed for many years previously in the city of Rome. It is explained that this system, even with its complicated switching devices and additional outlay in large generators, was found preferable, and at present cheaper, than to reconstruct the extensive underground wiring systems in the city. This explains the discrepancy in rated capacity between the turbines and generators.

Each unit has its own division on the switchboard, and the leads after leaving the bus bars pass through fuses to high tension oil switches, thence on to the line at 10,000 V. The transmission line, carried on steel lattice poles about

160 ft. apart, consists of two circuits 18 miles in length. Its course is, for the most part, alongside the canal across the Campagna Romana, which supplies modern Rome with water from the hills at Tivoli. While the poles are of steel, it is to be noted that the cross arms are of wood, a point on which Professor Mengarini, the technical director of the company is very positive as being necessary to good insulation. The insulators are porcelain triple petticoat, made by Richard Ginori, and instead of having their parts cemented, are sealed or "stuck together" in the burning oven: it is claimed in this, that all moisture is driven from the space between parts, that this space contains rarefied air, and that new moisture cannot enter. The insulators of this type for the new Subiaco line ("Modello 1905") for 30,000 V. are 9½" diameter and are tested to 60,000 V. At several points the line crosses railways and telegraph lines where safety devices are arranged to prevent accident from breakage of a high tension wire. Half-way is a switch and store-house having lightening arresters, and provided also with measuring instruments. Telegraph and telephone lines are carried on the same poles, alternated every 1,500 ft. to avoid induction.

The transmission line leads to Porta Pia, to a sub-station located on the northern side of the old city wall. This station, by the way, is situated at the point where Garibaldi's Italian army made the breach, and their famous entrance through the walls of the sacred city in 1870: the whole suburb in this locality is now a crowded modern city, with imposing buildings; so quick has been the growth of late years.

The Porta Pia sub-station reduces the line voltage as required for the different divisions of current demanded in the city. Lighting current at 2,000 V. is conducted to the underground cable systems for public arc lighting; mixed motor power and domestic lighting also at 2,000 V. is carried to numerous secondary sub-stations, whence it is stepped down to the consumers' tension, usually at 110 V.; the traction current is, after transformation, converted by rotaries to 500 volts D. C. There is also another portion of line current which is passed directly through four rotary converters for D. C. traction use, without the use of static transformers. In conjunction with the traction current a large accumulator battery is installed in this station, and is automatically thrown in or out to the amount required, by a very ingenious switching device, designed by Professor Mengarini. From a card of 24 hours performance of this apparatus, presented to the writer March 4th, 1906, the maximum variation of voltage shown on the lighting circuits is under 3 per cent. and the normal fluctuations rarely exceed 1 per cent. This is on a line interconnected,

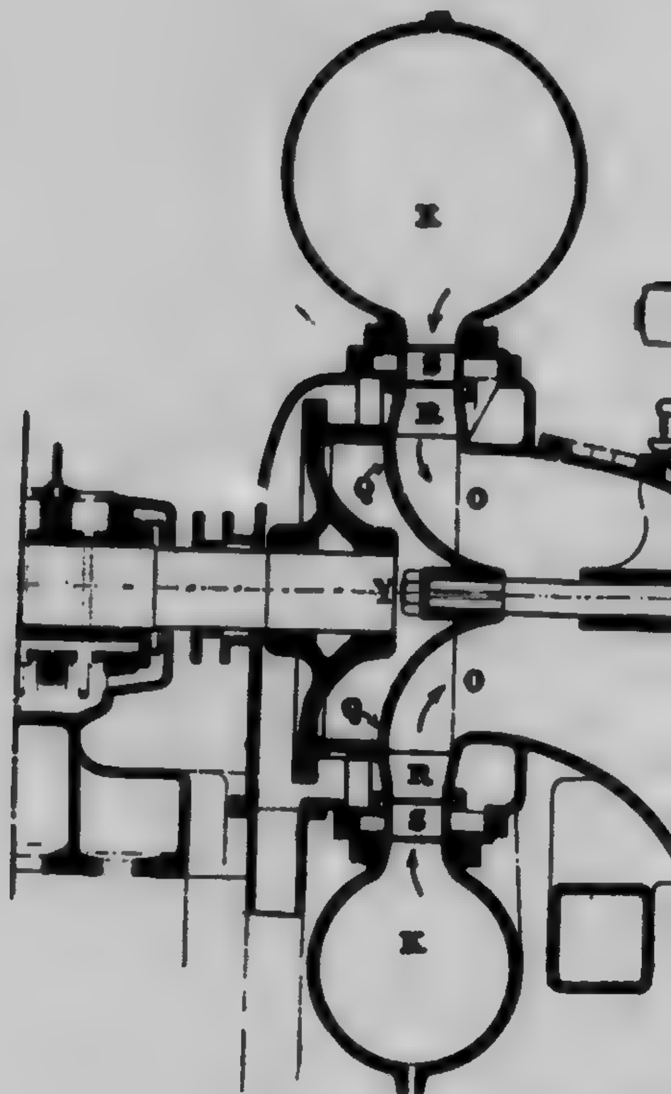
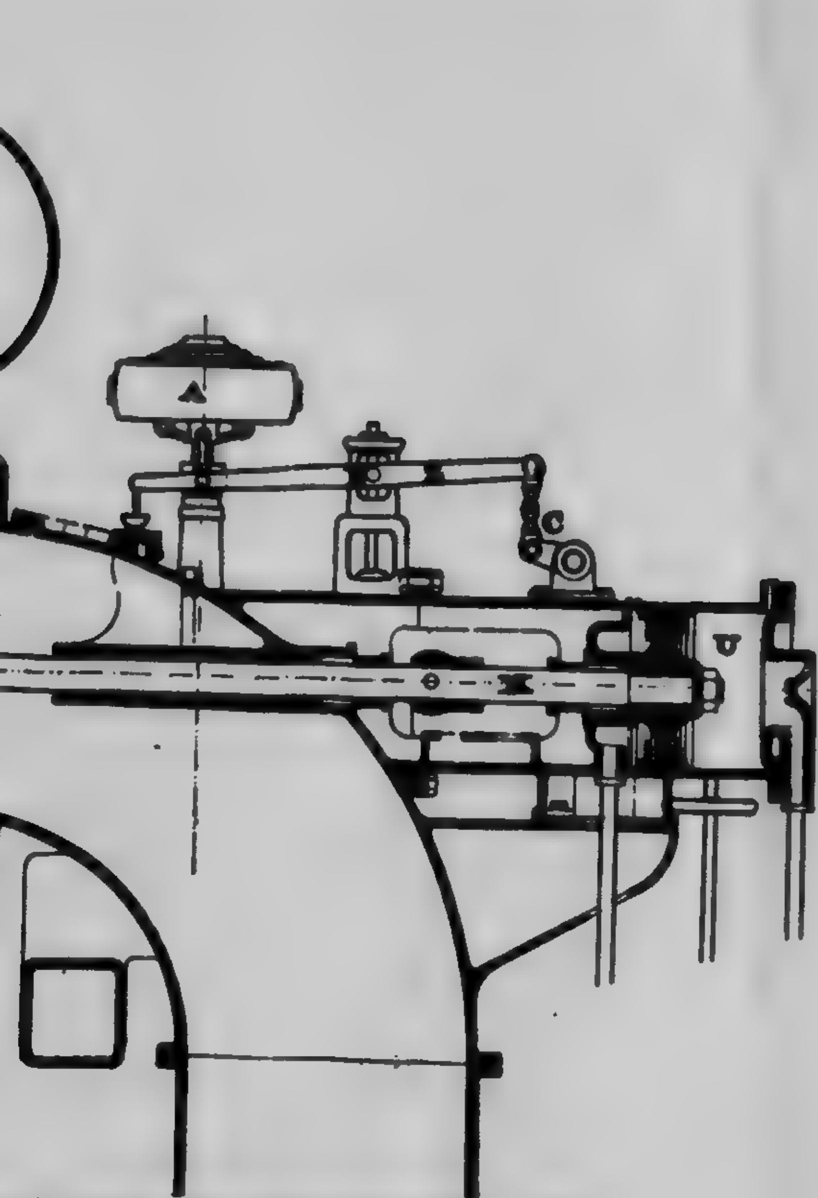


Fig. 4.—Tivoli Station: Francis Turbin



ancis Turbine, With Draft Tube Regulating Gates.

through the main transmission line, with a street railway system, in a city "built on seven hills" some of which are very steep. In this connection, Professor Mengarini pointed with pride to the incandescent 16 C.P. lamps in his office, at 6 p. m., which were as steady as any the writer has seen on the continent.

The auxilliary steam stations at Cerchi and Ponte Molle are in constant operation interconnected and, at times, in parallel with the hydraulic station.

Power prices in Rome are set forth at length in the "Regolamento per l'uso dell' Energia Elettrica." In general the prices run as follows: For small motors, about 6 to 8 cents per kilowatt hour; for large motors, on a 12-hour day basis, about $20 per H.P. year, and on a 24-hour day basis, about $35 to $40 per H.P. year. For lighting the price varies between 12 and 14 cents per kilowatt hour. The

Fig. 5.—Olevano Station: General View.

price of coal, however, is very high, being about $8 per ton.

The Neapolitan Plant at Olevano.

Southern Italy has never been looked upon as a favorable field for investment in the modern sense, and from an engineering point of view there has been little of interest beyond the railroads. As for manufacturing there has been small inducement except in the absolute necessities, because of the actual absence of coal or other fuel. But history here as elsewhere within the past twenty years, is repeating itself, and the water-powers have suddenly sprung into value, with the result that the twentieth century Italian financiers and engineers are turning to the south some of the energy already displayed in the north. Though called by the Italians "white coal" (carbone bianco) it cannot be a correct term in the French or Swiss sense, as there are no glaciers: nevertheless there are many streams of high head, and copious amounts of water.

As an example of this recent activity in development, the installation of the Societa Meridionale di Elettricita of Naples is taken as exhibiting interesting features. This installation first put into operation in January, 1905, is situated at Olevano, a little village in the Appenine mountains, about 50 miles south of Naples and 10 miles inland. The present capacity of the plant is 6,000 H.P., and ar-

Fig. 6.—Olevano Station: Penstock 40-inch Diameter.

rangements are made for extension to 9,000 H.P. The power is transmitted to various towns northward as far as Naples, including particularly Salerno, Nocera, Castellammare, Torre Annunziata (Pompeii), and Torre del Greco

(Herculaneum). The uses are mainly for lighting and mixed power in small units, such as fabric weaving, machine and wood working shops; but more than all, for the maccaroni factory, which is the flour mill of Italy. The network of wires extends widely among the towns at the base of Vesuvius, but fortunately suffered injury at only a few places during the recent disastrous eruption.

Fig. 7.—Olevano Station: Interior.

The plant is located on the Tusciano River, a mountain torrent in a valley rich with olive and fruit trees. (See Fig. 5.) The water is picked up at a high level, brought by a small canal and tunnels a distance of about 3 miles to

a sand box and forebay on the mountain side above the station. As the ultimate amount of water obtainable is only about 105 cubic feet per second, of which 70 cubic feet is now available, the headworks are of small dimensions. The water carries sand and is highly impregnated with lime, being a milky color, a feature which has given some trouble to wheels under the high head.

The penstock to the generating station is 40-inch minimum interior diameter, and is about 2,000 ft. long. It is carried down the mountain on 65 concrete saddles, and is supported by 17 heavy anchorages at the bends; the lowest portion is at an incline of 60 degrees where it is also supported by special structural steel towers. (See Fig. 6.) The lower end is horizontal, and distributed to 5 power and 2 exciter units; ultimately there will be 8 power units. This pipe is of sufficient size to supply water for all units at a

Fig. 8.—Olevano Station, Impulse Wheel, Showing Nozzles. (Case Removed.)

maximum velocity not exceeding 12 ft. per second, and is, of course, provided with a relief valve at the lower end, as well as with a drain valve. The thicknesses of sheets used in this penstock are as follows, heads being figured from forebay:—

200	ft.	head	¼"	thick
300	"	"	5/16"	"
380	"	"	⅜"	"
450	"	"	7/16"	"
550	"	"	½"	"
750	"	"	9/16"	"
860	"	"	⅝"	"
960	"	"	¾"	"

The plate rings are 5'-6" long, and are "inside and out-

side" lap. The penstock was built in sections about 33 ft. long, and bolted up on the ground.

In the generating station (Fig. 7) the five units at present installed are each of 1,200 H.P. output capacity. The water wheels are of a special horizontal shaft, impulse type, manufactured by Piccard Pictet & Co., Geneva, Switzerland; and are under 960 ft. static, and 930 ft. working head. They are rated nominally at 1,400 H.P., run at 500 R.P.M., and each uses about 14 cubic feet per second of water. The runner, 4'-8" diameter, consists of two heavy cast iron rims, having the steel vanes set between: this is mounted in a spider attached to the shaft. The water is introduced through a pair of nozzles at 90 degrees with each other, which are formed in one casting bolted to the end of the supply pipe; the nozzles lie up to the inner periphery of the runner and the latter discharges outwards similarly to the Girard turbine. The discharged water is caught in a tail

Fig. 9.—Olevano Station: Impulse Wheel With Governor. (Case Removed.)

pit below and the whole (pit and runner) is covered with a casing (see Fig 8), which shows the casing removed. The nozzles are opened and closed by a bronze tongue or throttle deflecting within the opening on a shaft which is linked up to the governor.

In the earliest nozzles on this type of wheel, the manufacturers had formed the whole nozzle head and tongue of bronze, an expensive feature in large units, especially when renewals are frequently required. Later types, however, such as the present, are built merely with bronze lips and tongue, as it is found that these—especially the lips—are cheaply and quickly renewed. The writer saw, and obtained a photograph of the eroded nozzle from one of the wheels in this installation, which had been in use 12 months: it pre-

sented a good object lesson of the power of sanded-water under high head. It is to be noted in this respect, that there is comparatively no erosion of the vanes of the runner under these conditions.

A mechanical governor is attached to each unit in the manner shown in Fig. 9. This has a particular sensitiveness for a simple mechanically geared apparatus, which is probably due to the extreme nicety with which adjustment can be made by means of liquid balancing in the glass jars shown on the rocker arm.

It is stated that in tests on these hydraulic units by the company, the following efficiencies were obtained: At full gate 76 per cent.; at three-quarter gate 73 per cent.; at half gate 68 per cent.; at quarter gate 62 per cent. The generators and electrical apparatus made by Westinghouse present no especially new features beyond the general modern practice of switching and isolation as designed by that house. The generators are three-phase wound to 3,000 V., and static oil-cooled transformers step up to 30,000 V. to the line, consisting of two trunk circuits which are carried on one line of structural steel poles about 180 ft. apart. The wires are 7 MM copper, and are 24 inches apart.

Prices for power in the cities named vary according to amount and distance from generating station. At Salerno, 16 miles distant, 200 H.P. is sold for $25 per H.P. year, on a 24-hour basis; larger blocks of power are sold nearer Naples at $30 per H.P. at 24 hours. There are two consumers near Naples using 800 and 1,000 H.P. each. Coal at Naples is about the same price as at Rome.

VI.

LOW HEAD SWISS INSTALLATIONS.

That Switzerland is the most interesting country in Europe is not a new announcement, nor an extreme statement. To the lover of nature the little republic in the Alps has long been the subject of many journeys, and to the Engineer, who among professional men is the closest to nature, it is beyond doubt one of the most inspiring regions wherein "the forces of nature are turned to the benefit and uses of man."

Viewed from the hydro-electric standpoint of engineering, Switzerland undoubtedly has led all other countries, and it is there the engineer must go, even to-day, to obtain ideas as far ahead of America as are the European fashions.

Fig. 1.— Chevres: General View of Station and Sluice Dam.

It is not the least surprising that Switzerland should maintain this proud position, because she has grown into it by sheer necessity. The country does not contain a pound of coal or other fuel, and it was to be expected that to the glacier fed streams and waterfalls the manufacturer and engineer would turn for his power. The result of this has been the gradual development of the turbine, the increasing of its efficiency, the introduction and adoption of ingenious methods of application and control of water. And when electrical transmission became a settled factor, the Swiss were quick to seize upon its advantages in conjunction with their hydraulic works, with the result that in many respects they are several years ahead of their neighbors.

It is the purpose of this article to describe several of the low-head Swiss installations, as illustrating types, old and new, now in successful operation. The Geneva plant

is perhaps the most generally interesting, combining as it does, a famous hydraulic work evolved from long experience and change, with modern electrical equipment to meet a peculiar market, and especially is it of interest because it is one of the few municipally owned plants in Europe, and at the same time is furnishing power at lower rates than most. The Rhinefelden and Rathausen plants are mainly of historical interest, while the Beznau works illustrate the latest practice under these conditions.

The Chevres Plant at Geneva.

The Chevres Plant is situated on the Rhone at a village called Vernier, about four miles below Geneva, which city is at the lower end of Lake Leman (or Geneva). The tributary river Aare, coming from the Alps in the region of Mt. Blanc, empties into the Rhone just above the works, and introduces an element of fluctuation into the head

Fig. 2.—Chevres: Stoney Sluice Gates.

water, which, however, in the main river, is controlled by works at Geneva at the outlet of the lake. The latter works were built in the eighties, and are provided with ingenious rolling slat regulator gates.

In general the power works consist of a main dam provided with sluices for immediate control of head water, an entrance canal and intake service extending upstream from the dam and a generating station parallel to the river, extending down stream, having the water introduced on the shore side of the house. Fig. 1 shows a general view.

The sluice weir has six gates of the Stoney type, each 33′-0″ wide and 28′-0″ high, built between piers, each of which is 56′-0″ long and 10′-0″ thick. The Stoney gates are of structural steel, counterbalanced and actuated with small hoists located on an overhead bridge, so adjusted that two men can raise or lower them by hand. Each gate weighs

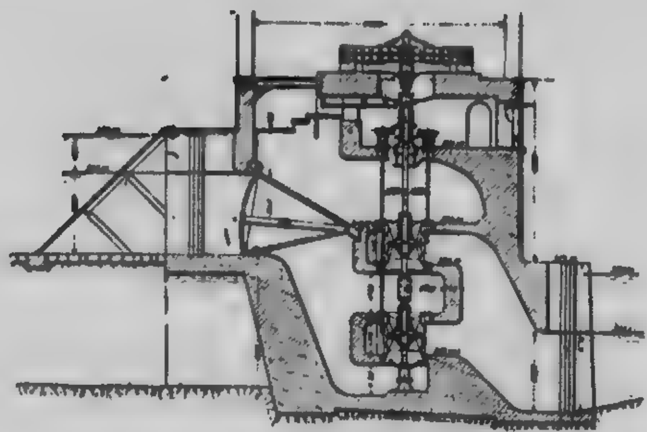


Fig. 3. Chevres: Section Through Unit.

fifty tons, and has three hundred and sixty tons water pressure against it when closed. Fig. 2 shows the general arrangement of these gates, and on the left hand are shown steel stop logs, to be used for closing off the head and tail water from any one gate, when necessary for repairs.

The dry weather flow of the Rhone at this point is about 4,200 sec. ft., occurring in winter, at which time there is a head of 28'-0"; in summer the flow is as high as 32,000 sec. ft., when the head is reduced to 15'-0".

In the original design it was found, in operation, that there were many defects, due doubtless, to meagre experience, at the time, in the requirements. One of the principal changes made in recent years was the construction of a wall from the upper end of the station upstream about 1,000'-0", forming with the shore a canal about 100'-0" wide, the upper end terminating at an intake provided with gates,

Fig. 4.—Chevres: Interior of Station.

thus permitting of the unwatering of the turbine inlets. In the same manner a training wall was inserted in the lower river, parallel with the station and about 50'-0" distant, forming a separate tail race. In order to further increase the head in the summer by slightly lowering the tail water, the ingenious scheme was adapted of placing the openings in this wall and creating an outward draft toward the main river, due to the high velocity of the latter.

By the new intake arrangement the first line of defence against ice, debris, etc., is now far upstream from the power house, instead of in a congested forebay in front of the building, an arrangement which has contributed in a large measure to the recent success of the plant, in securing continuous operation.

The generating station is 450'-0" long, and 41'-0" wide, and accommodates 15 vertical type power units and three exciters, as well as a complete oil pumping and filter plant,

Fig. 5.—Beznau: Interior of Generating Station.

a workshop and offices. All the building foundations and other works are built of concrete, resting upon sandstone ledge.

Of the fifteen units, ten are of relatively modern design, having been installed in 1899. The turbines, by Escher Wyss & Co. and the generators by Brown, Boveri & Co. These turbines are multiple-centrifugal, or outward discharge type, having four runners on each vertical shaft, specially designed for the high speed of 120 R.P.M. to obtain from 900 to 1,200 H.P., depending on head. They are designed so as to secure the best distribution of available water at any time by the variations of water areas, and are moreover arranged so that five of them will be used with the high winter head, and the other five with the low summer head. These turbines have ordinary thrust bearings,

three in number, and a foot bearing, all undue weight being supported by water pressure acting on the turbine wheels themselves. Regulation is done by oil pressure governors, actuating cylinder gates through vertical rack and pinion mechanism. Fig. 3 shows a section through one of these units.

With the five turbines of earlier type, however, when there is a high head, that is when tail water is low in winter, only the lower pair of runners is in operation, which when full open, develops 1,200 H.P. In summer with high tail water level and low head, both pairs are in operation, when each delivers 400 H.P. These turbines run at 80 R.P.M., and are conical in general shape with three guide rings to ensure even distribution of water to runners. The weight of the revolving parts is balanced by high pressure oil acting on the collar thrust bearings.

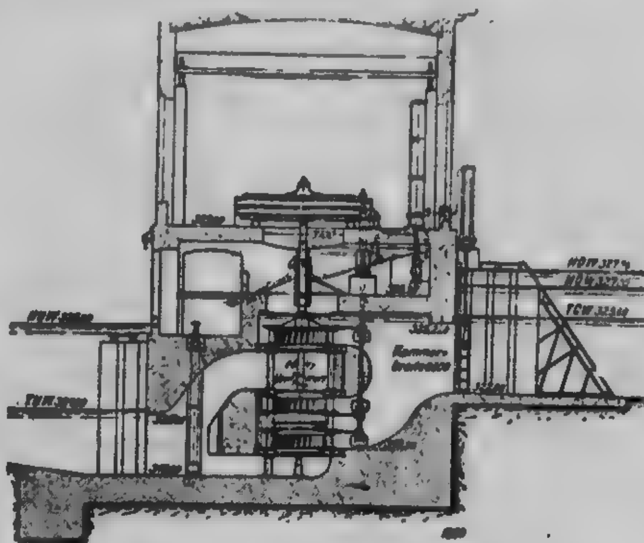


Fig. 6.—Beznau: Section through unit.

A peculiarity of these turbines is in the method of governing by a hydraulic servo motor, which provides that when the upper pair of wheels is not working, only the lower gates are operated, and when both pairs are working, regulation is obtained by the gates of the upper pair only. The wheel gates are moved in a rotary direction about the shaft by means of rocker and link motion.

The electric generators installed at the different times are of the same general umbrella type, but are of various windings. Eleven units are two-phase, 750 Kw., 2,750 volts at 45 cycles, five of which (earlier) have fixed fields, and six have revolving fields. Three units are two-phase, 5,000

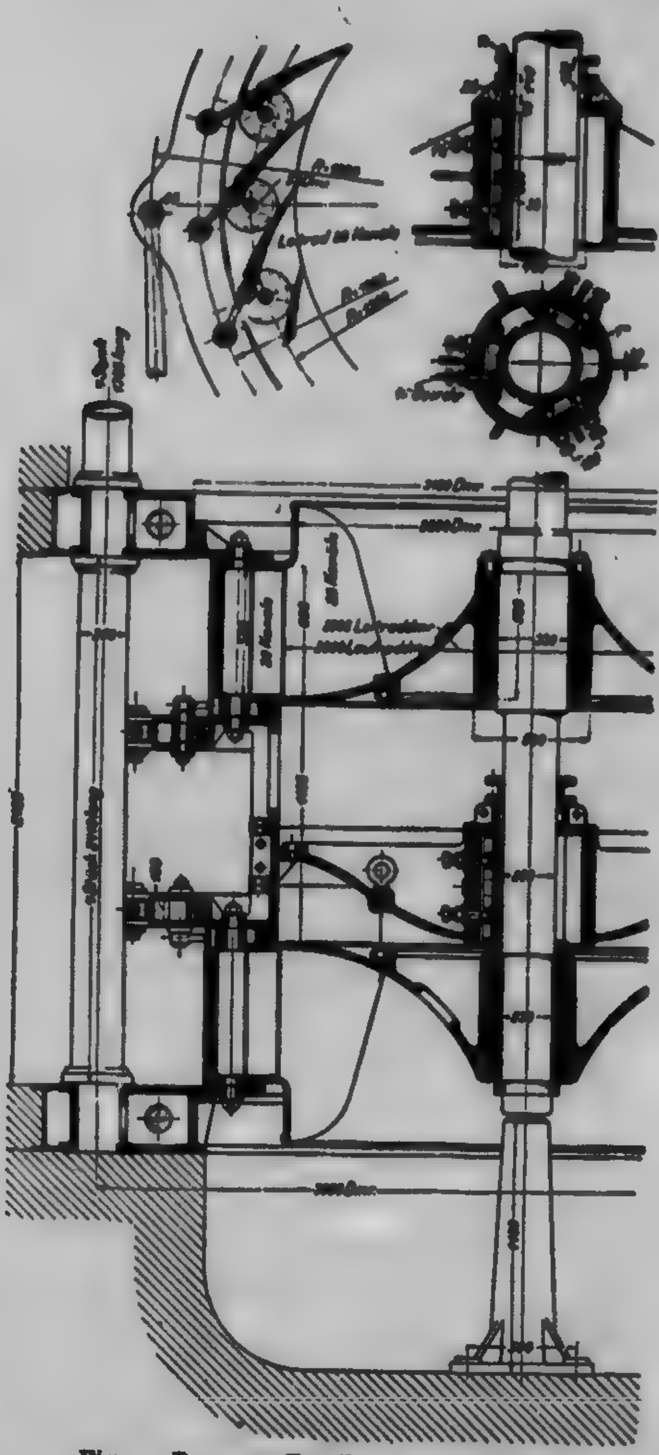


Fig. 7. Beznau:. Details of Turbine Unit.

volts, and one is a continuous current machine of Thury 12 pole type, supplying current to an electrochemical works nearby at 208 volts, owing to the small space originally allowed in the station for switchboards, etc., the switching devices are very crowded, so much so that several years ago a serious burn-out occurred; this has recently been remedied by additions to the building.

Perhaps the most interesting features of this plant are in connection with the distribution and use of the current. In no city in Europe does the number of consumers of power bear such a large ratio to the population. This means

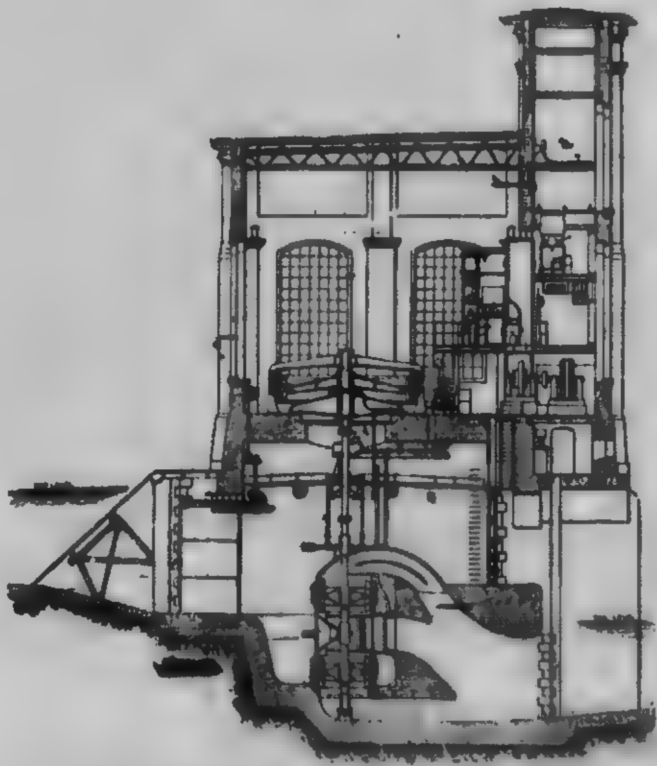


Fig. 8.—Rhinefelden: Section Through Unit

a very general use of small units, and a very extensive network of distribution lines. About half of the main lines, 90 miles, are still on towers, but they are gradually being put underground in tile ducts, and the engineers hope that within two years nearly all the main lines will be so carried. At numerous places, especially in the suburbs of the city, switching and transforming stations are situated. These are structures of steel and concrete, and are very compact and convenient.

The very general use of current in Geneva was evident in a short trip made by the writer, in company with the engineer, when a planing mill, a bakery, a jeweller's, a printing office and a chocolate factory were visited in which from 2 to 15 H.P. were used. The large number of takers under 2 H. P. was astonishing, and it may be noted that 113 of these small takers at 110 volts were using only 30.6 H. P. altogether, while 180 at 500 volts were using 1,261 H. P. at the end of 1905. The average power of all motors was 1.2 Kw. The total number of incandescent lamps in service at that time was 85,000. For the distribution of this power to 27 city and suburban localities 698 transformers in 83 sub-stations are required, being the largest number of any plant in Switzerland.

Prices charged by the city of Geneva are as follows: For lighting: 16 C.P. lamps (70 watts) one cent per hour, or 16 cents per Kw. hour, with large discount for a considerable number of lamps. For power: On flat rate, 1 H.P. at $64 per H.P. year; 10 H.P. at $43 per H.P. year; 20 H.P. at $32 per H.P. year; 50 H.P. at $28, and 100 H.P. at $22.40. These figures are based upon a ten-hour day with full advantage of the discount. A 24-hour day would increase the amounts by 50%. Coal for steam power is about $7.00 per ton.

The Beznau Plant, River Aare.

One of the most interesting low-head plants in Switzerland to-day is that situated on the Aare River, near Baden, known as the Beznau Station. In it are constituted all the most recent improvements in the application of the water to the wheels, and in the wheels themselves are embodied the results of the experience of the past ten years, with plants operating low-heads with large variations. This plant was completed and put into operation in 1904, and was quickly loaded up with consumers in the surrounding country.

The water is obtained by cutting across a bend in the river with a canal about three-quarters of a mile long and the generating station is placed across the lower end. A removable series of screens is provided, and also commodious spillways, although all ice and debris is deflected at the headworks. The generating station below the floor line is built of concrete, the superstructure being of stone.

The available fall varies between 10 and 15 feet, and, owing to this variation, the vertical turbine units consist of three runners 7'-6" diameter. One pair of runners is at the bottom, right and left, and the third above, discharging downwards into the draft chamber of the upper runner of the pair, see Fig. 6. At a medium head of 13'-0" 1,000 H. P. is obtained on each unit at 67 R.P.M., using 890 sec. ft. of water. The whole unit is supported by hydraulic pres-

sure beneath a disc, so as to reduce the weight on the step bearing, and the small inequalities of this are further balanced by oil pressure from special pumps.

Regulation is secured by an oil pressure governor geared to the main shaft, standing on the station floor, to which is attached to the gate shaft. Links from the latter are connected up to the gate rings surrounding the distributor of each runner: to the gate rings are linked the swivel gates, which, by rotating the ring, open and close on the fixed vanes of the distributor, thus admitting water as required to the runners. These details are shown in Fig. No. 7. The turbines are built by Theodor Bell & Co., of Kriens, near Lucerne.

The power secured in these units varies between 7,000 and 11,000 H.P. for the whole installation of nine units.

The generators are of the umbrella revolving field type, 800 Kw. each, three-phase, wound to 8,000 volts at

Fig. 9.—Rathausen: Gate Operating Mechanism.

50 cycles, and were built by Brown, Boveri & Co., of Baden. Local distribution is at the generating voltage, while long distance is at 25,000 volts up to 20 miles. The latter voltage was the highest in transmission operation in Switzerland at the end of 1905. The total length of transmission lines of this plant in 1905 was 70 miles, the number of localities served was 61, the population, 250,000, the number of transformers 60, and stations 31, while the average power of motors served was 100 Kw., in which respect this plant stands third in the country.

Prices of power are generally as follows: For lighting 16 C.P. lamps, $4 each per year, continuous service. For motors on 10-hour basis flat rate, 1 H.P. at $43; 10 H. P. at $39; 50 H.P. at $34, and 100 H. at $32. For 24-hour basis, 1 H.P. at $56; 10 H.P. at $49; 50 H.P. at $44, and 100 H.P. at $41.

Rhinefelden and Rathausen Plants.

A description of any low-head plants in Switzerland, however brief, would not be fair without some mention of the historical Rhinefelden and Rathausen plants, the former on the Rhine about 60 miles from Zurich, and the latter on the Reuss, near Lucerne.

The Rhinefelden installation, built in 1897, is still counted as one of the largest in Europe, being about 17,000 H.P., comprising 20 units under a head variable between 10.5 and 15'-0". The vertical shaft was adopted. Each unit has two turbines, consisting of a pair of runners, thus characterising the whole as a quadruple wheel unit, running at 55 R.P.M. The general arrangement is shown in Fig 8. In

Fig. 10.—11'-0" diameter Runner for 9'-0" head.

these turbines the weight of the rotor is borne by oil pressure from special pumps, and the regulation is effected by sluice rings, like the American cylinder gate, worked by an oil pressure governor. They were built by Escher Wyss & Co.

The headworks and station layout of the Rhinefelden plant is generally the same as the Chevres, in fact the exterior appearance of the station is quite similar, and the crowded condition of the interior is even more marked than in the Geneva plant. This in comparison with more

recent installations illustrates how the ideas of designing engineers, as to space required, have developed within the past twelve years. The head for these works is obtained by means of a sluice dam, about 1,000 ft. upstream from the station to which water is carried by means of a canal passing in front of the inlets in the same manner as at Chevres. The troubles due to ice and debris here are quite aggravated, in the spring especially, as there is no adequate relieving spillway. Upon the writer's visit to these works in May there were three shifts of twelve men each, raking grass and weeds from the screens, a condition which presents serious results in such a low-head plant.

Of the generators 11 are direct current at 140 and 155 volts, supplying electrochemical works adjacent; the other 9 are alternating at 6,800 volts for transmission short distances for light and motors. The electrical equipment was installed by the Allgemeine Elektricitats Gesellschaft (General Electric Co.), of Berlin.

The prices obtained for power by this plant are as follows: For lighting, 16 C. P. lamps $4 per each lamp. For power, metered, 1/6 cent per Kw. hour, and on a flat rate, 10 hour basis, up to 4 Kw., $40 per Kw. year; 40 to 80 Kw. at $30, and 160 to 300 Kw. at $24.

The Rathausen plant of early design, built about 1896, is typical of a simple low-head plant of the general style common in America, with vertical shafts, direct connected to generators. With a head from 12 to 16'-0" fed by a head canal alongside a rapid in the river. The station generates 1,600 H.P. hydraulically, and has also 1,400 H.P. in steam plant. There are five hydraulic units, consisting of single runners coupled to two-phase generators at 3,300 volts and 40 cycles. A feature of this plant is a device for closing butterfly valves in the turbine inlet flumes, two in each, an illustration of which is shown (Fig. 9). This plant serves 18 localities and a population of 22,000 people, with a maximum transmission of 8 miles.

To illustrate what one Swiss firm is doing in the manufacture of low-head turbines, a Francis type runner 11'-0" diameter is shown in Fig. 10, seen by the writer in the shops of Theodor Bell & Co. This was for installation under 9'-0" head, to give 600 H. P., and was cast in one piece.

VII.

HIGH HEAD SWISS PLANTS.

It is, perhaps, in hydraulic power practice under high heads, that Switzerland has attained her greatest distinction in engineering work. For this special branch, engineers, the world over, seek the advice of her manufacturers and designers, and in many cases purchase their equipment in that country. The latter custom has been quite marked in America during the past ten years, where high efficiency in large units has been desired.

Certain localities in Switzerland have been specially developed in this respect, but of recent years, with the advances

Fig. 1.—Kubel: Reservoir Dam.

made in electrical transmission, high head power plants have been constructed in many southern and western localities among the high Alps. These newer installations are all electrical, mainly for light and power purposes thus encouraging manufacturing in the surrounding districts. In the Bernese Oberland, and those districts north of Lake Geneva, new plants are being constantly projected and constructed.

To illustrate this recent development a schedule, based on reports of 1905, is given below, presenting twelve representative plants, which have commenced operations within the past few years. That at Aigle with its head of 3,140'-0" is still said to be the highest in the world.

Principal High-head Swiss Plants.

PLANT AND LOCATION.	Horse Power	Head Feet	Local's served	Miles. Length of Lines	Miles. Max. Trans.	Pop. to be served
Aigle, near Territet ..	2,000	3,140	25	32	15	30,000
Bex, l'Avancon River .	2,400	530	9	40	35	5,700
Engelberg, for Lucerne	8,000	1,030	12	30	23	40,000
Kander, at Spiez	6,000	280	35	150	35	100,000
Kubel, at St. Gall ...	5,600	270	23	32	20	70,000
Montbovon, Saane Rvr.	5,400	220	68	165	35	58,000
Montreaux-Territet . .	3,900	810	12	11	8	30,000
St. Maurice, for Laus'ne	5,200	122	8	50	40	60,000
Thusis, Upper Rhine .	3,580	300	1	2	1	1,300
Vaud at Vallorbe . . .	5,000	770	30	60	30	100,000
Vernayaz, Rhone River..	1,800	1,910	11	25	22	14,000
Wadenswil, Sihl River	2,000	230	18	55	14	34,000

Fig. 2.—Kubel: Abutment of Self-supporting Penstock.

For the purposes of this article the following three typical installations are selected from the above, as embodying interesting features of design and construction.

The Kubel Plant Near St. Gall.

The Kubel plant is situated at Bruggen, a suburb of St. Gall, in north-eastern Switzerland, on the River Sitter. This work, commenced in 1899, and first put in operation in 1901, was constructed to meet the great demand for cheap electric power in St. Gall and the surrounding towns. This region is the main silk and cotton spinning and weaving centre of the country, and consequently has a large demand for small units in motors. St. Gall has a population of about 50,000, and with the surrounding region this plant was, in 1905, serving about 70,000 people in 23 localities. To do this there were 35 sub-stations, with 135 transformers, having an average of about 33 k.w. for each transformer, a total of 4,400 kilowatts.

In general the system of development consists of a series of collecting dams, tunnels, and flumes, bringing water from the upper levels of the tributary streams to a high level valley above the ravine in which the power station is situated. The water is brought down to the station by penstocks and is discharged into the river alongside. In this way 5,600 H.P. is obtained hydraulically under 270'-0" head, and in addition the station has a 1,000 H.P. steam unit as a [illegible].

At the present time the water is collected at a point on the Urnasch tributary, about 3½ miles from the station. The first control is by a concrete dam about 12'-0" high and 150'-0" long. At one end of this an intake, at right angles, leads to a head tunnel, and is provided with head gates and a coarse rack. In front and rear of head gates are sluices through the dam 5'-6" and 3'-6" diameter respectively, for draining the stream bed and intake. The head tunnel is driven through rock and is about 15,000'-0" in length with a horse-shoe section, lined with concrete, 6'-0" high inside. This tunnel empties into a reservoir formed by two dams across a valley, transverse to the Sitter River, thus providing a forebay of large area.

The end of the forebay farther from the power station is closed by an earth dam about 1,000'-0" long and 45'-0" maximum height, while the lower end is crossed by a most substantial stone dam, see Fig. 1. The latter dam has a total height of 80'-0", is of gravity type, with a top width of 10'-0" and a bottom width of 50'-0". It is arranged with a low level discharge gate leading to the penstocks, and has an overflow weir in front (left of illustration) which carries surplus water around end of dam. Under working conditions the head water stands from 3 to 5'-0" below the coping.

From the dam two steel penstocks 5'-3" diameter lead down the valley and slope to the power station a total horizontal distance of 900'-0". These run side by side and at a maximum slope of 76%. The one first built crosses the Sitter River to the station on a steel lattice bridge, distributing in front of the building into right angle branches serving the wheels. A second penstock, installed for extensions, spans the river without a truss, forming an arch in itself sufficient to carry the combined dead and live loads. This is also connected to the distributing main which supplies 7 units from the two interconnected penstocks. The details of this arched penstock are of special interest and Fig. 2 shows the abutment casting, which serves also as a two way elbow, one side being to the distributor and one to a pound unit.

The power station is a plain, rather American looking, brick building on a concrete foundation, and at the time of the writer's visit, May, 1906, temporary extensions of wood had been made pending permanent construction.

The power units indicate an interesting evolution so common in present day practice in power stations the world over. The first hydraulic installation had four 500 H.P. units of single nozzle Pelton type impulse wheels by Escher Wyss & Co. Then one 1,200 H.P. unit of the same type was added. Then came a 1,000 H.P. vertical reciprocating steam engine unit to act as a reserve, due to fear of water shortage. After this more water was secured, a second penstock connected up and a second 1,200 H.P. impulse unit was installed. Early in the present year a third 1,200 H.P. unit, by Theodore Bell & Company was added, but of the Francis reaction type. The change from impulse to reaction is due to the fact that the latter has now attained a stage in design so as to be adapted for heads approaching 300'-0".

The impulse wheels of 500 H.P. have a single tangential nozzle on each of two runners in the same case, while

Fig. 3.—Kubel: Interior of Station.

those of 1,200 H.P. have three nozzles on each, or six to the unit. The former revolve at 375 and the latter 300 R.P.M. Referring to Fig. 4, it will be seen that the water is controlled by tips linked to the governor by rocker arms, and that the jets are deflected when not in use. The outside diameter of these runners is 50" and the unit, when loaded, consumes about 40 cubic feet of water per second. Although impulse wheels they are set 20 feet above tail water having draft tubes which are fitted with air valves to admit sufficient air to prevent the water level rising as high as the wheels. The governors are operated hydraulically by means of pressure from the supply pipe with which the governor cylinders are connected by piping. Admission of water to the latter is regulated by a fly ball governor and delay piston.

In the electrical equipment no particularly unique features are incorporated, as all power is distributed at the generating voltage, 10,000 V., without transformation. The generators are all of the same type of the various powers and are by Lachmeyer & Co., of Frankfort. The exciters are directly connected on ends of generator shafts. The whole station is arranged to run in parallel through either of two bus systems.

In order to form an idea of the cost of such projects, according to European practice, the following approximate figures are given for this particular work, assumed to the end of 1904, when 4,200 hydraulic, and 1,000 steam power was available on the shaft corresponding to about 3,600 kilowatts for delivery.

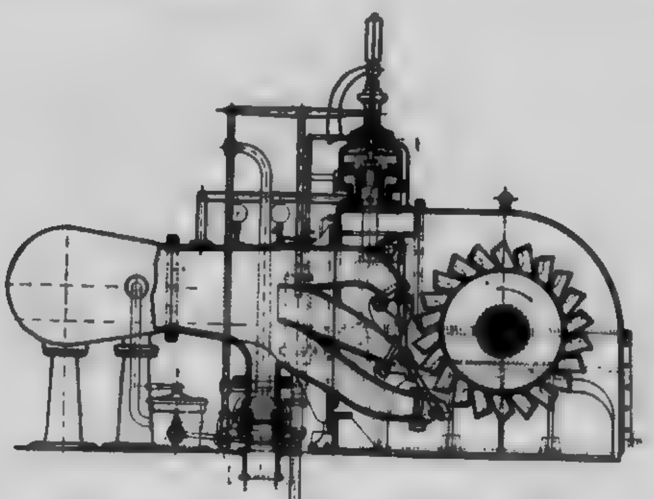


Fig. 4.—Kubel: Section Through 1,200 H. P. Wheel.

A.	Preliminary, concessions and lands		$170,000
B.	General Works:—		
	Collecting dam, etc.	$ 15,600	
	Head tunnel	146,000	
	Reservoir dams	135,000	
	Penstocks, overflows, valves, etc.	47,000	
	Power station structure	66,400	410,000
C.	Hydraulic equipment		29,000
D.	Steam equipment		36,000
E.	Electrical Equipment:—		
	In power station	109,000	
	Distribution, transformer stations, etc.	320,000	429,000
	Total		$1,074,000

In the above it must be noted that portions of classes A, B and E are available against extensions so that ultimately the capital cost per kilowatt would be much reduced. Thus while the cost as shown is almost $300 per kilowatt it may subsequently fall to $200 when the plant is developed to its [redacted].

The sale of power from this plant is in a flourishing condition and the market has quite exceeded the facilities. For lighting, prices obtained for 16 C.P. lamps are from $2.50 per year for 400 hours to $4.50, using 1,500 hours per year,

Fig. 5.—Vallorbe: General View of Station.

such as required in residences at all times or in offices and factories until 6 p.m. For motor load, prices are as follows: One H.P. $80 per year; 5 H.P. $65; 10 H.P. $55; 20 H. P. $45; 50 H.P. $36.

The Vallorbe Development.

Vallorbe is a small city in Canton Vaud, situated on l'Orbe River, a short distance north of Lake de Joux, and

about two miles from the French frontier. The river empties from the lake, which is 800'-0" above the valley, through an underground passage beneath Mount d'Orzeires, and emerges after its downward rush at the foot of a high cliff, about a mile and a half from the lake. This gigantic bubbling spring is called Source de l"Orbe—and thence down to Lake Neuchatel the river flows through a deep and beautifully wooded valley, sufficiently picturesque with its cascades and waterfalls, to attract thousands of summer visitors. This is now one of the tourist points on the new Paris-Simplon-Milan line.

In the autumn of 1901 the "Compagnie Vaudoise des forces motrices des lacs de Joux et de l'Orbe" was formed to develop, generate and distribute electrical energy in the Canton and, as the first of their enterprises, commenced in 1902 the construction of a hydro-electric plant near the

Fig. 6.—Vallorbe: 1,000 H. P. Power Unit.

"source" called La Dernier station. This station and its local distributing system were put into operation in 1904, and was soon followed by a second plant, 10 miles lower down on the riyer, at the city of Orbe, the latter called the Montcherand station. These two plants when entirely completed will deliver for sale about 11,000 H.P., which they consider will be a minimum continuous output. The region in which this is sold is quite large and may be said to comprise all that south-western portion of Switzerland lying between Lakes Geneva and Neuchatel (excluding Geneva and district).

The Vallorbe plant has been in operation since 1904 with five units: space and connections are arranged, however, for three more, while ultimate extensions will provide for a total of about 12 units if sufficient water can be secured. The present output of this plant is 5,000 H.P.

Hydraulically this development is most remarkable, owing to the nature of the water supply. Lakes de Joux and Brenet have six and seven surface outlets respectively, but the main discharge is the subterranean river which forms the Orbe. In order to get sufficient water then, all the small surface outlets were dammed, and the lakes were formed into a huge reservoir in which the concessions permitted the fluctuation of the level within limits of 12'-0", artificially controlled. At certain periods of the year these lakes have regularly risen a number of feet, according to a law deter-

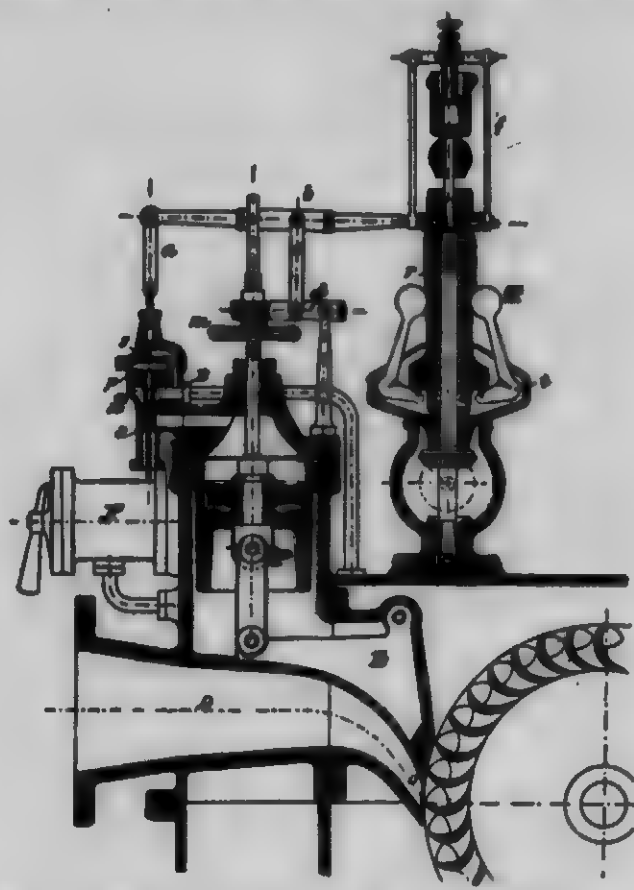


Fig. 7.—Vallorbe: Section Through Hydraulic Governor.

mined by observations extending over many years. This increase is now partially secured by the new works, and is held up for power purposes. The subterranean flow, however, still proceeds. Hence the development presents the unique feature of being dependent entirely on storage water or such as can be stolen from the natural outlet. Probably when some ingenious Swiss engineer obtains a means of plugging

the outlets in the bed of the lake, or can find and tunnel into the subterranean rivers and dam them, the present plant will be developed to much larger proportions.

The water taken at the intake in the lake, after passing racks and gates, is carried by means of a rectangular concrete lined tunnel to a point on the lower hillside, where a forebay and head house are located. The tunnel conduit is 6'6" wide, 7'-0" high and about 8,700'-0" long on a slope of 3%.

In Fig. No. 5 the forebay works can be seen high up the mountain side. Water issuing from the tunnel first passes a course rack, enters a chamber having an overflow weir with adjustable crest, then passes through a fine rack and enters a second chamber at right angles to the line of flow, thence passing head gates, enters the penstocks. Overflow water spills into a large chamber from which steel pipes carry it down the slope. In the illustration the latter, two in number, are on the left, and the single penstock leads toward the right, passing into the rear of the station parallel with the long axis. The penstock varies in diameter from 48" at the top to 40" at the station, the respective thicknesses of plates being 5-16" and 13-16", while the distributor portion within the building is 1". The total length of penstock is about 2,000'-0", with a maximum slope of 77%; it is carried on concrete piers with heavy anchorages and there are four expansion joints.

Fig. 8.—Vallorbe: Water Resistance Lightning Arrester.

The two spill pipes are about 2,400'-0" long, about 3'-0" diameter, 7-16" plate, and with rivets counter sunk on inside. These have several expansion joints and automatic air entry valves. They discharge water into the river below the power house.

In a plain concrete building are now installed five 1,000 H.P. units and two exciters operating under a head of

770'-0". These units (see Fig. 6) are contained in a room 160'-0" long and 40'-0" wide, while in a central wing are located the busses, switches, switchboards and arresters.

The water wheels are by Escher Wyss & Co., and are very similar to the 500 H.P. units in the Kubel plant, having single nozzles with one runner. A feature of this wheel is its automatic hydraulic regulator, an illustration of which is given (Fig. 7) showing governor and link connection. In plants of this pressure, European builders are using filtered

Fig. 9.—Vallorbe: Artistic Isolated Transformer Station.

water from the penstock instead of oil as the medium. This involves a mechanical filter on the governor to insure clean water. Escher Wyss have what they call a "revolving filter," F, which can be worked by hand. The cycle of operation from the fly balls to the relay valve, with its fine adjustment to prevent "racing," through the lever system to the regulating valve S, thence to the main cylinder and piston P, and to the throttling lip L, can be readily followed. A pressure

regulator is also attached to each unit for relieving sudden excess pressure on the supply pipes and penstock.

The generators are built by the Oerlikon shops, and are 3-phase 50 cycles, wound to 13,500 volts at a speed of 375 R.P.M.; they are connected to the wheels with Zodel coup-

Fig. 10.—Engelberg: General View of Station.

lings. The switching is specially interesting, owing to the wide system of distribution, but is simplified by having no transformers. Instrument pedestals of American type are

installed, and the chief operator from his gallery can easily control all operations of the station. A unique arrangement of hydraulic jet lightning arresters is installed on a floor above the gallery, shown in Fig. 8. This combines a horn type arrester with a water resistance together with a choke coil and metallic ground wire.

For the distribution of this power and that from the lower station there is planned a network of over 250 miles of line, the farthest point served being about 50 miles distant. A characteristic is the widely scattered network of power service. The total population in the localities is about 100,000, the number of localities or communes designed to be served is 212 with 235 transformer stations. This is a striking example of the extensive detail of distribution which European companies are now carrying out, and both the people and the power companies of Ontario can at the present time benefit materially by following Swiss lead in this respect.

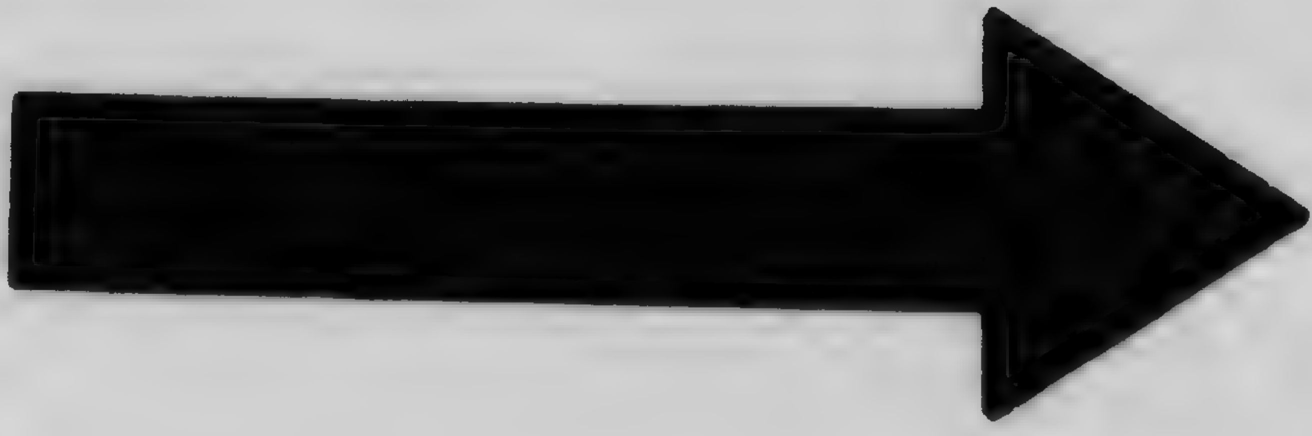
To illustrate this widely scattered market the following table is given, showing the number of localities and respective populations in which the company's franchise permits sale of power for 30 years, subject to state controlled prices:—

10	communes	under	100 inhabitants.	
48	"	from	100 to 200	inhabitants.
55	"	"	200 to 300	"
59	"	"	300 to 500	"
21	"	"	500 to 800	"
10	"	"	800 to 1,200	"
5	"	"	1,200 to 2,000	"
4	"	"	2,000 to 5,000	"

The power in these places is used for lighting, street railways, cement and brick yards, all manner of agricultural needs, such as churning, etc., watch-making, weaving, and miscellaneous shops and industries.

Small transforming stations of standard design, about 10'-0" x 12'-0" inside and 27'-0" high with 3 floors, are erected in many localities. These are built of brick or concrete and are cheap and neat in appearance. Some in city streets and parks are most artistic. See Fig. 9.

Prices are as follows:—For light; 16 C.P. lamps from 400 to 800 hours per year, \$3.60; over 800 hours, \$4.40. For heating: 8 cents per kilowatt hour. For motors flat rate: on 11 hour basis, less than 1 H.P., \$60 per year; 1 to 2 H.P., \$40; 9 to 11 H.P., \$37; 25 H.P., \$33; 50 H.P., \$30; 100 H.P., \$29. On 24 hour basis add 25% to above figures. For motors on meter rates from 2.5 cents per kw. hour at 1 H.P. down to 1.4 cents at 100 H.P.



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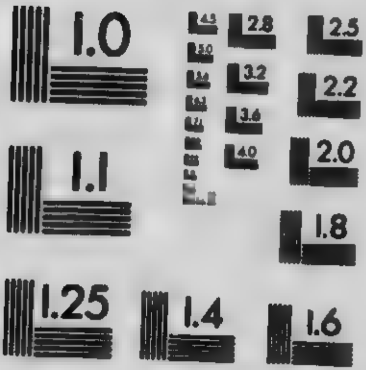

The Engelberg Plant.

Among the new Swiss installations that near Engelberg, about 20 miles from Lucerne, stands out most prominently. The construction of this plant was commenced late in 1903, and it was put in operation in the fall of 1905. It is organized by Lucerne promotors and nearly all the stock is owned by the city corporation as a financial investment, but the company is operated privately. The principal market is in the city of Lucerne for lighting and power, and a considerable block is taken for the Engelberg 3-phase electric railway. The interest in this plant is in its modern equipment both hydraulic and electric, and it may be considered an example of the latest European practice.

Engelberg, town and district, are well-known to tourists as a summer and winter resort high in the mountains south of Lake Lucerne. The little Erlenbach rises in the hills near-

Fig. 11.—Engelberg: Penstock End and Its Distributor.

by and forms a small lake before starting down the valley. This lake provides the head pond of the power works, and is arranged as a storage reservoir. Water is taken through a small intake with gates and screens and is carried through a tunnel 6'-6" diameter about 8,500'-0" long, on a slope of 0.12% to a small reservoir on the mountain side above the power station. This head house is provided with gates and screens and the water feeds into four penstocks each 40" diameter. Two of these tubes are now erected and connected to water wheels. The total length of penstocks is 2,100'-0", giving a head of 1,030'-0", under which the wheels operate. The penstocks were constructed in 25'-0" lengths and bolted in place. They are each provided with five sliding expansion joints, with five heavy anchorages and are carried on concrete piers. At the lower end the sheets are 1" thick and at the upper ⅜". The distributors at the station branch

each to 3 units, while the two exciter branches are connected to each tube; each has a butterfly valve, a guard plate, relief and emptying valve. Fig. No. 11 shows this arrangement.

The power station is a dignified castle-like structure built of limestone, in pleasing harmony with the massive cliffs and tree-clad mountains surrounding it. In the interior, the striking feature is the generous space provided for all apparatus. The generating room does not present the usual appearance of overcrowding, but with very ample floor space and lofty roof and windows. Even the power units look small if not lonely. The roominess of switch-board galleries and switching equipment chambers is quite as well marked as also is the great space allotted to the transformers, arresters, etc. The engineers look upon this as one of the modern features and in fact the writer saw no European plant with greater space given to this apparatus.

Four main power units are now installed, each having a capacity of 2,500-H.P. in the wheels and an output from the

Fig. 12.—Engelberg: Interior of Station.

generators of 1,500-kw. Two exciter units are operated independently. Another separate unit of 600-H.P. furnishes power for the electric railway.

The water wheels, manufactured by Theodore Bell & Co., Kriens, are the Pelton impulse type with double buckets and side discharge. See Figures 12 and 13. They have one runner driven by a single nozzle having a throttling gate governed by a water pressure governor.

The alternators were built in 1904 at the Oerlikon works and are wound to 6,000 volts at 50 cycles at a speed of 300 revolutions per minute.

Local switching equipment controlling the power units is installed on the same floor as the generators. Shunt regulators for exciters and exciter rheostats are mounted on a mezzanine gallery. Transformers are on the ground floor

and consist at present of two banks of three and three single phase with one reserve. Oil switches are provided on both low and high tension sides, the latter being at 27,000 volts. Bus bar compartments on ground and first floor are made thoroughly fire-proof, and in addition to spacious size are particularly well isolated between circuits. The lightning arresters are Siemens double horn pattern arranged also with water resistance and choke coils connected in series. Distant control in convenient arrangement with centralization of instruments and recording apparatus is a marked feature.

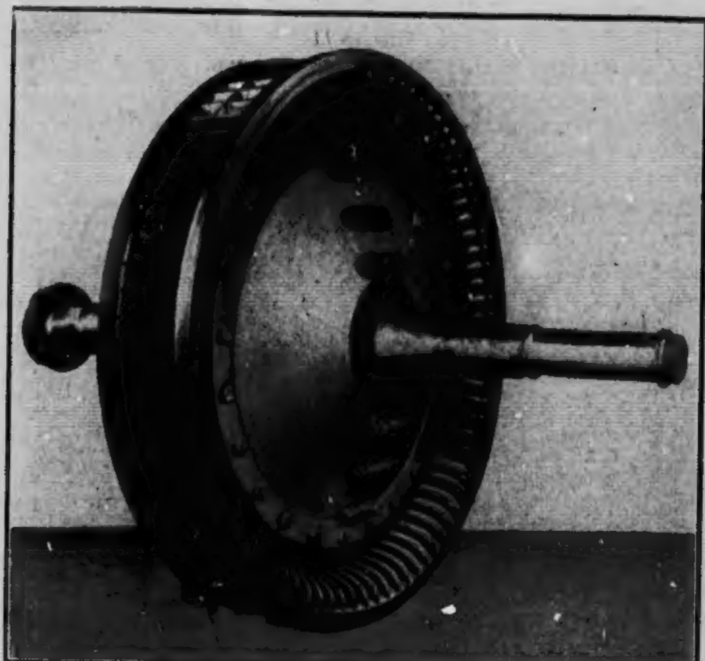

Fig. 13.—Engelberg: 2,500 H. P. Impulse Wheel.

In addition to the power supplied to Lucerne, about 400 kilowatts is used in the Engelberg Districts. Fortunately the peak load for Lucerne occurs in the summer period when there is ample water for the plant. The A. C. electric railway from Stanstadt to Engelberg, about 15 miles in length, is newly constructed on the three-phase design and has proved a great success. A portion of the line, near the power station, is rack and pinion at 30% grade and is operated by electric locomotives, this road being one of the first to depart, in this respect, from the well-tried steam engine type.